Ordering Principles in a Dynamic World of Change

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Ordering Principles in a Dynamic World of Change

On social complexity, transformation and the conditions for balancing purposeful interventions and spontaneous change

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Abstract

Consider autonomous, discontinuous and non-linear change a constant factor in the transformative world we humans are part of: Heraclitus revisited. What seems to be stable is nothing more than a temporary period of persistence, a frozen moment within a dynamic world, the lee-side of a world in flow. As there is no permanent stability, tensions, frictions, mismatches and breaks occur more or less constantly. Such a situation is not necessarily

undesirable. On the contrary, these tensions, frictions and mismatches prove to be essential for development and progress. This contribution will construct a frame of reference for such a world of discontinuous change, proposing ordering principles that can guide planners and decision-makers in a world of non-linear change.

The ordering principles that meet this task are conditions and are an intrinsic part of a transformative environment to which a situation or system responds. Here, these are referred to as *contingent* and *adaptive transformative conditions*. Two interrelated models will be introduced to elucidate these conditions and their relevance to framing change, development and transformation. The models will reveal the conditions with which a situation or system has to comply to be able to respond, coevolve and adapt within a dynamic environment.

Both models have their own history and are fed by various theoretical debates. Moreover, they not only combine the technical and the communicative sides of planning. They also bridge the 'static' world of planning with the non-linear, dynamic and transformative world on which the Complexity Sciences focus. The combination of the two models, in conjunction with the transformative conditions these models produce, will work as a frame of reference for planners and decision-makers who must cope with non-linear, transformative change.

This frame of reference is strongly related to, resonates with and nicely defines 'social complexity' – a field within the Complexity Sciences that is still an underdeveloped area of research. While both planning and social complexity address the material and immaterial, social complexity incorporates concepts of non-linear change relevant to transformative environments. Human settlements such as cities are examples of these transformative environments.

Cities are human achievements that are in a continuous process of construction, redevelopment and transformation, ensuring liveability for people, supporting societal development and allowing people to socialize. The Complexity Sciences consider cities as complex adaptive systems which are open to change and therefore transformative in character. Considering cities as non-linear, dynamic and unstable is probably more realistic than seeing them as nothing but stable, linear and certain.

In unstable, non-linear and transformative environments, transformative conditions become relevant. These conditions are points of reference in a continuous process of cities seeking but never reaching for long, if at all, a balanced, healthy state. This results in a trajectory that cities and every other complex adaptive system may follow in seeking new paths, progressing and consequently transforming. This also means that transformative conditions generate a new kind of knowledge, and can be seen as ordering principles in a dynamic world of change. The question is how to identify these transformative conditions as parameters of non-linear change.

1. The reality of evolution and revolution

Revolution and evolution are expressions of change which occurs without thoughtful planning, ranging from abrupt transformations to almost invisible adjustments. This strongly contrasts with the planner's usual perspective of intentional intervention, which focuses on space and places as they 'are' and on how they should be, based on an expert's opinion or on agreement or consensus. Traditionally, a planner is concerned about effectively intervening in space and place, hence the desire for controlled environments. Contemporary planners also prefer to act on the basis of consensus among the various parties involved, to create a world which is agreed upon. The message here is not that these approaches are bad, wrong or outdated; on the contrary, it is just that there is more involved. Revolution, evolution, or whatever kind of contextual, spontaneous and unintended change, is also in the air, and usually not part of most planners' ideas about how the world should look.

Therefore, here the traditional and contemporary view of planning will be challenged. This traditional view ranges from a controlled world and a *factual reality* to an environment which gains meaning through consensus about an *agreed reality*. The message of this contribution is that in addition to controlled environments and agreed realities, it is reasonable to accept that our daily environment may be full of unintended, autonomous and surprising change. We had better learn to live with this, whether we like it or not.

Autonomous, unintended and spontaneous change implicitly affirms the relevance of time. Looking back in time brings to light the non-linear course of many developments, both socially and spatially. With respect to revolutions and evolutions, let us step back in time a little and take a moment to consider, for example, the impact of the French Revolution, which elevated the mob to the level of civil society, and therefore fundamentally changed the world of choice, decision-making and planning. The French Revolution began in 1789 and led to voting rights for all men in the second half of the nineteenth century, followed by women in the early twentieth century. Another social project, which at that time resonated through various societal developments, including spatial planning, was Ebenezer Howard's Garden City. This was more than a spatial proposal, as it also ardently addressed a social agenda. This social project continued in the twentieth century.

Despite revolutions and evolutions elevating people as citizens, it is only since the 1960s that planners have turned their attention to the voice of society, with Davidoff's advocacy planning (1965), Friedmann's transactive planning (1973) and Forester's ideas for a critical theory of planning (1977) all representing a change in attitude towards a notion of a responsible society capable of becoming more involved in spatial transformations (Fischer & Forester, 1993; Friedmann, 1987). Eventually, this change in planners' attitudes resulted in a true paradigm shift – a scientific revolution – around 1990. This shift is also known as the 'communicative turn in planning', and a distancing from a technical attitude to planning. Consequently, shared governance approaches were embraced, albeit half-heartedly, as the involvement of society was not entirely the result of a voluntarily gesture made by planners and decision-makers. The communicative turn was also due to a lack of funding, a decline in authority, the rise of opposing stakeholders and a growing awareness of the powers of stakeholders (Forester, 1989). The legacy of the French Revolution was turning into an evolutionary trajectory, full of sudden, surprising and transformative developments, which at some point in time forced the planning profession to adapt to the circumstances. In other words, the communicative turn in the discipline of planning was a product of a long-term, non-linear kind of development.

The days of planners being the sole experts on how the daily environment is shaped are behind us. Their ability to produce straightforward and definitive answers to spatial problems is now labelled as 'primitive optimism' (Voogd, 2004: 15) and 'functional determinism' (Alexander, 1986). Consequently, in the early 1990s, the theoretical debate shifted focus away from linear reasoning and controlled outcomes. Shifts in everyday planning practice were less clear, but were unavoidable due to examples of failure in policies aiming to exert control.

At various moments, planning practice had to endure surprising, if not revolutionary, developments. Most notable were the 2008 housing, mortgage and financial crises, which came as a complete surprise to most experts. It had a devastating effect on citizens, cities and urban development across the globe. Planners stood aghast and watched it all happen, powerless to stop the destructive avalanche of financial and urban misery.

Beyond the control of planners, economists and governments, paths of an entirely different nature can be observed running in parallel to the crises, seemingly unaffected by it. Although having had its own bubbles in the past, the information society continued evolving spontaneously, effectively and rapidly, with the digital environment being transformed in an unprecedented way: a development not constrained by the global instability of financial markets. Moreover, the way digital innovation has invaded physical space and the rapid rise of virtual realities have also had an unprecedented effect on society. This digital revolution and its impact on space and society is seemingly unstoppable.

There is more to observe with regard to change. Society today is highly educated and, thanks to the digital era, also well informed. Consequently, civil society is becoming a critical and capable society, ready to step into what some call the post-policy era (Swyngedouw, 2010) to take responsibility and the lead in processes of spatial transformation. Consequently society's attitudes are changing. A critical society wants to be involved in and, indeed, responsible for decisions about the kind of spatial interventions that are necessary (De Jong, 2016; Warren, 2009). This critical society also wants a say in determining the contributions these interventions should make regarding the quality of life and the environment. This societal transformation influences the role of planners, as well as the position that planning takes in relation to the urban and to society.

Such non-linear developments are very much real, they do matter and do have an impact. There is no other way than to conclude that change is not only intentionally created by experts. In fact, it is all around us, it is interrelated, it is present in many and plural ways, impacting on space and society. The question then is: Could and should this unintended, spontaneous and uncontrollable change become an intrinsic part of spatial planning, reflected in its language, attitude, models and debate?

2. The storyline

Below, the word ‘systems’ will be used to designate situations, cases and issues.

This introduction to a world that is open to autonomous and discontinuous change will now continue by connecting it with the Complexity Sciences. This aim is to inform planners and decision-makers about how transformative worlds relate to the idea of non-linear development. Non-linear development can be seen in the very systems representing a dynamic world in change, affected as these are by flows of energy, matter and information, which come from the system’s environment, transit through it, and is partially absorbed by it. Within the Complexity Sciences, these systems susceptible to change are considered to be ‘out-of-equilibrium’. These systems will thus continuously seek a good fit and a balance, internally and with the contextual environment, and as such follow unstable paths, transforming and coevolving structurally and functionally.

This brings the story to explain that systems that are able to transform and coevolve ‘at the edge of order and chaos’ are ‘complex adaptive systems’ (Gros, 2008). Human settlements, villages, towns, cities and urban regions are considered to be such systems. This will be made explicit in analysing the transformative and evolutionary behaviour of settlements through the ages. Recognizing settlements as complex adaptive systems will also present planners and decision-makers with an example of how to model various and related trajectories of change.

This contribution will continue explaining that being ‘out-of-equilibrium’ limits planners’ ability to refer to systems in terms of content, process and purposefully constructed conventions in their attempt to exercise some form of control. These limitations to their capabilities, however, are not necessarily problematic, with the story shifting to *transformative conditions*. Transformative conditions are considered to be an intrinsic part of systems and their transformative capacities. These allow these systems to progress along their unstable paths. In this contribution, transformative conditions are presented as ordering principles and as a frame of reference for systems that are open to non-linear change.

The story continues with two kinds of transformative conditions: one for slow and one for sudden transformative situations. Attention goes first to those conditions relevant in slow transformative situations: *contingent transformative conditions*. These conditions are particularly relevant within a relative stable but transformative environment, within which systems perform, progress and are transformed. The next step will be to look at situations within which systems encounter 'turbulence', which challenges the system's capacity to continue performing 'steadily'. Instead these systems may 'bifurcate' and coevolve to a new level of relative stability. However, such turbulence is not only responsible for systems bifurcating, as the relevance of contingent transformative conditions will diminish, with the system's *adaptive transformative conditions* taking over.

By recognizing these transformations, the coevolutionary process undergone by a complex adaptive system can be understood, explained, followed and eventually manipulated. Transformative conditions are an intrinsic part of the system itself, which allow systems to adapt to the outside world and to self-organize internally, while transforming and coevolving at the same time. Knowledge about these conditions supports the understanding of a transformative world.

This brings us to the topic of the final part of the paper: What are the institutional and theoretical consequences of this reasoning about non-linearity, change and transformation? What is the relevance of transformative conditions for planning and decision-making? And how do contingent and adaptive transformative conditions relate to planners' institutional design processes and to the theoretical debate in planning and decision-making?

These questions lead to four conclusions. The first concerns change being conditioned by contingent relationships when systems are well embedded within a relatively stable environment. The capacity of systems to transform is manifest as *transformative space*, which is defined by its contingent conditions and keeps the system on track towards the future. Change will be adaptively conditioned if the system is pushed off track, with dynamics throughout, and *bifurcation* towards another level of relative stability.

Secondly, each open system, situation, issue and environment is by definition transformative and conditioned. Contextual environments have an impact on systems, through which these systems coevolve, adapt, self-organize and therefore transform, while coevolving, adapting and self-organizing systems also affect their environments.

Consequently, and thirdly, there is insight into the system's transformative behaviour. This conclusion is not merely relevant as such. It also provides a bridge to the arena of human interventions and the role of institutional design: humans and their institutions should be willing and capable of 'reading' systems and their transformative capacity, as well as the trajectory these take and the characteristics and exposure of these systems along this path. Thereby, they will have to understand the contingent and adaptive transformative conditions that are relevant to systems and their capacity to develop, and to which the planners' desire to interfere also relates.

The fourth conclusion concerns the theoretical debate on spatial planning itself being subject to processes of non-linear change, with the debate coevolving and transforming rationalities. In other words, the theoretical debate in planning is also conditioned and therefore open to change.

This contribution thus wishes to understand processes of non-linear, discontinuous change, which are seen as the consequence of systems' transformative conditions resulting in *conditioned trajectories of transformation*. This understanding of transitions, non-linear developments and progress, contributes to the debate about planning and decision-making, and it touches on the world of social complexity.

3. A world that 'is', is not there

The world of social complexity concerns humanity and its environment – a human world full of change, which affects each and every one of us in various ways. It is hard to ignore the sudden and rapid changes which are occurring all around us: the turmoil of the early twenty-first century, generating all kinds of societal emotions, such as fear (as the result of terrorism, migration and globalism) and amazement (from unexpected political developments to virtual discoveries). Far-reaching consequences, such as financial crises and digital revolutions, are all having an impact on the urban and our personal lives. While we might wonder how real the threat of terrorism is (according to some, the world is actually becoming safer, see www.ourworldindata.org; Gat, 2006; Pinker, 2011), the 9-11 attack definitely changed the global agenda on security overnight. It also triggered a chain of events, including war and revolutions, which resulted in millions of people on the move. The desire to migrate to safer places made visible the thresholds of the capacity to absorb massive numbers of people from different cultures, countered by the rise of nationalism and a call for respect for local identities. These concerns in Western societies are also a response to failing financial and global policies, encouraged by the 'establishment' and its global orientation. In various countries in the Western world many people have discovered that, after the 2008 housing crisis, it is impossible to sell their property, which suddenly confronted them with an entirely different perspective on their future.

Meanwhile, the revolution taking place within the digital world is seemingly unaffected by these real and symbolic threats. The digital world has had its own crash, the dot-com bubble, ten years earlier. But more than anything it is innovative power through which the digital world is affecting people and society in an unprecedented way. Most people have incorporated the concept of instant access to information, yet are unaware of the next phase, in which each and every one of us function 24-7 as information-gathering sensors, on the basis of which 'the cloud' generates profiles, preferences and attitudes better than we could do ourselves. Many of us have experienced the amusement of play in virtual worlds which the iPad, Xbox and Playstation have brought to our lives. Through digital channels, as well as sensors and cameras found everywhere, every incident, wherever it occurs on the globe, affects every one of us immediately and with full force. This creates instant awareness of events and shows the extremes of and frequent fluctuations in the societal impact. While people perceive increasing dynamics everywhere, most would like to hold on to certain things as well, as points of reference that they would prefer to remain as they are. This duality can be found at every level of existence; and it is a duality which is hard to reconcile.

This duality is also visible in planning. In contrast to these dynamic times, planning has a history of being in control and taking the lead in spatial development, with planners seeing themselves as instigators, intentionally transforming a designated space into a predefined place. This is a one-sided perspective with a strong focus on the world as it 'is'. It consists of the intention to solve problems, preferably permanently, and conceives that with every problem solved, we are one step closer to a perfect world. However, this implies a world which is stable, where problems are isolated within space and are inert, only changing as a result of the purposeful interventions of the planner. Does such an ideal world exist at all? A world which is not affected by unintended change, interventions, conflict, trends or disruption is a closed world. This notion brings to mind extreme examples, such as Disney World Orlando, purposefully planned to be an enjoyable place, a utopia within reach if you can afford it (Kunstler, 1993), and at the other end of the spectrum, places such as North Korea and Belarus, which are not immediately praised for their unique selling points, but are often referred to as dystopias.

Of course, today there are few planners who assume that there will come a time when all spatial issues will have been dealt with, resulting in an ideal world. Nevertheless, this history of planning as in control and creating a world to our liking is a paradigm which is difficult to overcome. While planners know that such a world cannot be created under each and every condition, this idea of 'the world as it should be' is certainly a powerful point of reference. Moreover, it is not only planners who remain attached to this paradigm, as most of society also desires a sense of control. This idea of humankind being in control of a world which is shaped according to our liking, with the planner as the creator and initiator, is still very much alive: functionality, considered as the paradigm of the previous century, is still very much a part of our thinking (Ambrose, 1986; Geyer, 2004).

It is hard to escape this proposition; it is what the twentieth century made us. It even affects people's idea of change, which is viewed in the light of a world that 'is'. If there is spontaneous change, it is regarded as an anomaly and, consequently, is immediately adjusted or encompassed within an understanding of the world to be. It is remarkable how readily people take change for granted: most people would have to make a serious effort to remember how things were before the smart phone, the internet or cash machines. In this respect, people live in a culture of 'instant satisfiers', we are fast adapters and happy appliers, and we maintain our comfort zone based on the assurance that we humans are the creators of our own environment, we are in control and 'it' is working; even if we know we are not. Being is the master and functionality is its apprentice.

4. What about a world of 'becoming'?

Every human being develops a particular mind-set that frames how they act in the world of which they are a part. However, such mind-sets displace much that lies outside one's field of vision. Consequently, people persist in considering the world to be as they see it (Barley & Tolbert, 1997; Faherty, 2016; Kahneman, 2011). People readily ignore other possibilities and alternative views, even if they are obvious, such as the idea of 'a world in change'.

This persistence of a belief in a world that 'is' has its history, which might go all the way back to Parmenides (around 500 BC) and his poem 'On Nature'. In this poem, he presents *Alétheia* ('Reality') as 'what is'; reality considered as 'is', rather than 'what is not', which cannot 'be'. Moreover, 'what is' cannot change or become something else, what it is not (Heidegger, 1992; Popper, 2012). The Arabic Golden Age of Science (800 to 1200 AD) continued thinking within this framework of a world that 'is', introducing the 'academic' method of creating factual and objective knowledge. The idea of this method is, of course, that observations result in scientific abstractions, which should be dealt with methodologically, and should lead to critical reflections in support of alternative ideas which coincide with our observations. However, what often happens instead is a confirmation of the existing paradigm (Kuhn, 1962). Paradigms are not easily overcome.

Since the late nineteenth century, an awareness has arisen among scholars that what they observe is not fully objective, not value free, but constrained by particular, popular and successful perspectives, which function as a frame of reference (Doucet, 1984; O'Riordan, 1976; Ward, 1997; Weber, 1949). Nevertheless, facts, quantitative analysis and evidence-based practices are still seen by many today as *the* route to the 'truth'; a true world that 'is', ever so often being a truth in disguise.

Apparently, people need to be aware of what to expect before actually seeing and observing it. This may also explain why scientific developments are strongly paradigmatic: they tell scientists what to expect and what they are meant to see. If the focus is framed by the idea that the world is in a permanent state of 'being', it is likely they merely see this world in a permanent state, while the world is actually 'becoming' and in constant change.

It is not difficult to construct a convincing narrative around the issue of a dynamic world of change. An important step to take in this respect is to include time and generate some sense of history. Consider, for example, the flow of ideologies that tell us how to take on the world. History shows how society's desires are evolving, if not also revolving; there are global economic trends, technical innovations and demographic shifts which affect everyone's daily lives. Furthermore, in the domain of spatial planning, planners cannot ignore shifts in governance, from command-and-control to participative, communicative and collaborative approaches within the domain of shared governance (Allmendinger, 2009; De Roo, 2003). Planners can see dynamic patterns of development when looking at a city's past and considering its route to the future (Geddes, 1915/1968; Hall, 1988; Mumford, 1961). In other words, it is almost impossible to ignore that various processes of change are happening, and this process is revolutionary and evolutionary, as well as ranging from predictable to spontaneous and sudden change. The easy answer is to say that planners should adapt to this and get on with it. The difficulty is that intentionally adapting to a new frame of reference is almost impossible, expressed in notions such as 'paradigm shift', 'scientific revolution' and 'fundamental break'.

This contribution explores a kind of reasoning that leads to alternative frames of reference, taking a position in which discontinuous change is a major factor in the world of which humans are a part. What seems to be stable is, from this position, nothing more than a temporary period of persistence, a frozen moment within a dynamic world, the lee-side of a world in flow. In generic terms, a dynamic world in change is to be considered 'out-of-equilibrium'. This results in a *transformative world*, within which systems adapt and self-organize to adjust and to reposition themselves externally and internally moving towards a new state in accordance with their 'conditions of change'. 'All free-living systems are nonequilibrium systems', as Kauffman concluded (1995: 21), and these will never reach permanent equilibrium. As he also pointed out, biologists consider a state of equilibrium to be a dead state (Kauffman, 1995).

We consider a world in change as a world which no longer 'is', with no definitive end to problems, and no utopia within reach. The realization of a utopia would be a *contradictio in terminis* anyway. As there is no permanent stability, should planners expect an ideal situation to be within reach? Or will planners have to acknowledge tensions, frictions, mismatches and breaks as occurring more or less permanently and as essential to transformative environments (De Roo, 2016a; Weinstock, 2010)? If so, this would mean planners must continuously consider and reconsider how the world around them is ‘becoming’ and what they must adapt to (De Roo, 2012; Hillier, 2006).

This understanding is fundamental: with humans – the planner in particular – no longer the sole creators of space and place, it is possible to consider a world which, at least partially, creates itself without purposeful intervention, often developing beyond our control and progressing autonomously despite our intentions. Consider the planner and the development of a new neighbourhood in a built-up area. Is the planner creating the neighbourhood, or responding to a demographic shift at the macro level, with urban growth as a consequence? It is fair to say a bit of both might occur, with the planner supporting a particular macro shift, facilitating housing development, coherently, effectively and affordably, and fine-tuning based on the needs and desires of individuals at the micro level. In addition to the planner being a spatial designer or a mediator among stakeholders, it would also be worthwhile to consider the planner as a specialist in and a guide through autonomous and non-linear change.

5. Time, non-linearity and the Complexity Sciences

The twentieth century can be regarded as the functional era. However, in the same period, scientific progress made clear that the foundation of functionality is no longer solid and sound (Nordin, 2006). Certainty, the ultimate goal of the ‘enlightenment’, considered to be at the heart of the ‘age of reason’ and behind the pursuit of knowledge, embraced as the scientific ‘raison d’être’ for understanding the world, was no longer viewed as completely reliable, thus challenging the traditional route to ‘truth’. The concept of certainty was already questioned in the early twentieth century. If one wants to pinpoint a particular moment in time in which certainty lost its absolute sense at the human level, and its position as the supreme aim of knowledge, to which the social sciences also wished to contribute, it could well be 1963.

A century ago, certainty lost its fundamental position in the ‘exact’ sciences due to the theories of Poincaré (the three-body problem), Einstein (relativity of time and space) and

Heisenberg (the uncertainty principle in quantum mechanics) (Prigogine, 1996). These theories did not necessarily lead to the conclusion that certainty had lost its meaning at the human level – Newtonian physics is still more applicable to our daily lives than Einstein's theory of relativity. Nevertheless, 50 years ago, fundamental uncertainty was introduced as an 'undeniable fact' at the human level.

In 1963, Edward Lorenz (1917–2008), mathematician and meteorologist, published an article which had a tremendous impact on science and our worldview. Lorenz (1996) pointed to systems within our daily environment which respond in non-linear and, therefore, unpredictable ways. Meteorologists in the 1950s, like all other scientists at the time, struggled with the limitations of models based on mathematical formulas which were relatively simple, and which straightforwardly described a reality which barely behaved in a decent, orderly and predictable manner. Meteorologists were meant to predict the weather, and their systemic approach was initially linear. 'Linear' means proportionality first and foremost: 'B' increases with 'A' and in the same ratio as 'A'.

The models used by Lorenz were no longer linear in the sense of using formulas that were related to clear, fixed and independent variables to produce straightforward and undisputable outcomes. The variables Lorenz used in his models generated outcomes which were not regarded as end products but were reintroduced into the model at a later stage as inputs. This consequently resulted in an iterative process based on feedback and feedforward loops. This approach is also common in the population sciences: the number of children produced by one generation – obviously – becomes the input in the next generation producing offspring (Findlay & Mulder, 2015). In the same manner, the weather could also no longer be seen as an isolated phenomenon. It was recognized that the atmospheric context had a major influence, largely determining the weather conditions. Like demographic developments, these atmospheric currents were neither linear nor stable but found to generate dynamic change. These rather crucial environmental factors were thus found to influence the weather, and were therefore introduced into the dynamic weather prediction models with which Lorenz was working.

Lorenz (1996) noticed a strong deviation in results when repeating his calculations using the same input. True, the model was dynamic and contextual fluctuations were included, but even so, repeating the same calculation using the same input should yield the same output.

However, Lorenz noticed that while he was using more or less the same input, the calculations generated substantial differences. While he was using the same numbers, he varied somewhat using every now and then a different number of decimal points. For example, instead of using 76.853 over and over again, he had also used the shorter form of 76.8. Dynamic and iterative models, however, are able to produce major differences from inputs which hardly differ.

In Lorenz' model this small difference at the beginning of the calculations resulted in output which would not be expected in a linear and proportional world. This is a consequence of circular causality, which became known as the 'Butterfly Effect'. It is a metaphor for a small event (the butterfly flapping its wings) triggering turbulence which at some point evolves into an avalanche of events that have a major impact (a hurricane of devastating force). As no observation of the weather at any location is completely precise, and consequently comes with small variations in measurements, this means that the impact of contextual dynamics on the predictability of the weather is huge. The consequences of this discovery were substantial and fundamental: it meant the end of exactness and the scientific claim to certainty.

Keeping the context out of the equation is what made laboratories quite successful in their contribution to knowledge. Isolated events were measured, over and over again. This reductionist approach revealed a reality in its most elementary sense. However, only under one condition: the context must either be excluded or completely stable and not able to interfere. Obviously, this does not work very well for weather forecasts, for population dynamics, and for much more. Economic progression, urban transformations and societal developments all occur in an environment which is open and dynamic (Sedlácek, 2011). Studying these processes in isolation would be foolish. Nevertheless, that is what was generally considered the correct scientific approach, and it had been applied for decades, if not centuries.

Lorenz was building on models which had been proposed by mathematicians such as Turing (1912–1954), and Russian scholars such as Lyapunov (1857–1918), Minorsky (1885–1970) and Lefschetz (1884–1972) (see Keller, 2009). At the turn of the twentieth century, Russians were producing work on stability in non-linear dynamic systems. This became relevant to Lorenz, Ruelle (1989) and others in the work they were doing in the 1960s on system dynamics, turbulence and phase transitions. In 1975, Li and Yorke used the term 'chaos' to label non-linear deterministic systems and their unpredictable behaviour. Their idea was just one step away from what became known as 'chaos theory' (Cruchtfield et al., 1986; Gleick, 1987) and the study of systems confronted with and influenced by unstable contexts: these were known as disrupted states, due to ambiguous contextual disturbances, also known as perturbations.

6. Dissipative systems open to energy, matter and information

What had happened was in essence quite crucial: mathematics was able to explain the growth and decline of a variable (e.g. population size and a discrete-time demographic model; see May, 1976) using fairly simple and straightforward axioms iteratively, where every outcome was the input for the next round of calculations. Feigenbaum (1983) used the axiom y = rx(1-x) to show development through time, with each outcome 'y' becoming input 'x' for the next calculation. The result is very convincing: depending on 'r' – the 'degree of non-linearity' (Gleick, 1987) – development can progress along three possible paths: linearly, by simply dying out, or exhibiting chaotic behaviour. Basically, this axiom offers a non-linear model which in an elementary and uncomplicated way explains behaviour in biology, ecology, demography and meteorology. It also explains non-linear urban development, with the city being a non-linear deterministic system exhibiting unpredictable behaviour. In other words, the powerful message of mathematics aligns with the dynamics of environmental behaviour.

Consequently, academic interest in a contextual and dynamic world rapidly increased in the 1980s (Waldrop, 1992). Various fields of research, including chaos theory, were grouped together in the 1990s into what became known as the Complexity Sciences (Keller, 2009). In the last decade or two, a wide variety of lines of research have been developed with a focus on non-linearity. They include self-organization (Heylighen, 2001; Portugali, 2000), coevolution (Garnsey & McGlade, 2006), transitions (Geels, 2013), complex adaptive systems (Cilliers, 1998; Miller and Page, 2007), socioecological systems (Holling, 2001; Kauffman, 1990), resilience (Davoudi, 2012; Folke, 2006) and, central to this contribution, *transformative change*. All these notions, concepts and ideas refer to a world which is open, contextual and dynamic, and which behaves non-linearly and unpredictably.

Although he was not alone, as others such as Haken and Eigen made their own wonderful contributions, much attention and credit goes to Prigogine (1917-2003), a Belgian scientist who was originally from Russia, who studied dynamic systems in the field of thermodynamics. He referred to these dynamic systems as 'dissipative' (Nicolis and Prigogine, 1977). This means that systems – non-linear and dynamic – are open to energy, matter and information. Such systems not only pass on energy, matter and information but are also able to absorb these and be affected by them (Figure 3). This ability supports the movement of processes of evolution and development in a direction opposite to the universal increase of entropy (in abstract terms: a continuous loss of energy, an increasing disorder of matter and a lack of information, Daintith, 2005; in concrete terms: a house not being taken care of, and not absorbing energy, matter or information, will eventually collapse). The behaviour of such systems cannot be viewed in isolation. They can only be understood in relation to their environment; the context with which they have an interdependent relationship, exchanging energy, matter and information. How promising is this for those disciplines with a focus on social life: sociology and its sub-discipline, spatial planning?

This question brings to mind the work of Patrick Geddes (1854–1932), a much appreciated planning scholar and originally a biologist. Geddes was well aware of Darwin's theory of evolution, a theory of the non-linear and transformative development of living systems (species), which he adapted to the world of settlements, towns and cities. He was a contemporary of Ebenezer Howard (1850–1928), with whom he shared environmental concerns and concern about social deprivation. This led him to criticize urbanization and to develop an understanding of the energy and material entering into, passing through and exiting the urban domain (Geddes, 1915). Decades later, Wolman (1965) labelled this view 'the Metabolism of Cities'. In conjunction with various peeks in environmental consciousness within society, various concepts and tools have been produced since then, including material flow analysis, urban metabolic measures, sustainability indicators, energy transition, ecosystems services and resilience, just to name a few. This notion of urban metabolism (Baccini, 2007; Newman, 1999) relates strongly to the concept of dissipative systems.

7. Planning and complexity teaming up

Crosby was responsible for a work bringing 'together for the first time […] lines of research that promise to illuminate the social and economic functioning of cities and regions as nonlinear, dynamic systems' (1983: v). The work includes a preface by Prigogine and a contribution by Allen (1983), who attempted to connect Prigogine's abstract idea of dissipative systems to the 'evolution of urban structures'. This work assisted spatial modellers to develop a spatial understanding of non-linearity. However, it did not have a great effect within the wider planning community, if it was known at all.

Around the same time, Christensen (1985) published her seminal article on complexity, in which she acknowledged that reality is 'much more complex', with different levels of uncertainty in terms of means and ends. Her argument was in the tradition of Thompson (1967), who proposed the combining of open system strategies with closed system strategies. For two decades, her contribution was considered a point of reference by planners. However, the way she addressed the inevitability of uncertainty and complexity as a concept relevant to planning and its institutional environments was primarily object oriented, with reference to a functional world and the technical-rational side of planning. It concerned a world that 'is' rather than a world of 'becoming'. Thus, Christensen's notion of complexity is above all a 'static' one.

What Christensen did implicitly in 1985 (see also Christensen, 1999), and what De Roo explicitly proposed ten years later (Bartelds & De Roo, 1995: 87; Borst et al., 1995: 34-43; De Roo, 1996, 1999: 12-18) was the differentiation of planning issues on the basis of *degrees of complexity* (See as well Hayek's 'theory of complex phenomena', 1967; Nagel, 1962). Aware of Christensen's work – and with reference to the ideas of complexity of the theorist Stuart Kauffman (1990), who distinguished traditional systems, calling them 'static' – De Roo (1999, 2003) and Zuidema (2014) introduced 'static' complexity into the domain of planning.

One of their reasons for distinguishing ‘degrees of complexity’ was to divide the contemporary debate on planning theory into simple and straightforward issues (blueprint planning), complex, circular issues (scenario planning) and highly complex issues that could be found within open environments (network planning). Contingency theory also lay behind their decision to differentiate planning issues according to ‘degrees of complexity’. The third reason was to be able to bridge the divide between the ‘static’, a-temporal but differentiated world of planning and the Complexity Sciences, with their dynamic, time-related yet undifferentiated worldview.

This means there are thus two kinds of complexity to consider: a ‘static’ kind of complexity – complexity within the world as it ‘is’, with an emphasis on the here and now, on ‘being’ – and a ‘dynamic’ kind of complexity – representing a ‘becoming’, a world in flow, within which situations, issues and systems survive amidst order and chaos: a world ‘out-of-equilibrium’. A static kind of complexity supports the idea of a differentiated world at a fixed moment in time. This kind of complexity can only be perceived if time is left out of the equation: a world that is fixed and frozen.

De Roo and Zuidema take the position that contemporary planning theory has its focus, by and large, on a world that ‘is’. The consequence is that planning theory is somewhat a-temporal. This, of course, is peculiar, as planning should be about interventions that result in desired environments at some point in the future. If time was added, they argue, a non-linear kind of rationale would have to emerge; and this non-linear rationale connects with the Complexity Sciences. Taking the step to include time, so they reason, could bridge the divide between contemporary planning theory and the idea of purposeful interventions, and the spontaneous transforming world of the Complexity Sciences.

This is what a handful of spatial modellers (Allen, 1997; Batty, 2005; Batty and Longley, 1994; Frankhauser, 1998; Pumain & Saint-Julien, 2010; Torrens, 2012) had been doing for some time. They had been developing and working with non-linear models, trying to understand the transformation of space and place through time. To do so, they made use of quantitative data from GIS, cellular automata and agent-based modelling. Within the planning community, these modellers were regarded and treated as a separate group and worked somewhat in isolation from those who were theme-oriented, conceptual or theoretical planners.

One could arguably point to July 2005 as the moment the Complexity Sciences were embraced as a serious theme by the wider community of planning scholars. It was on that date that the Association of European Schools of Planning (Aesop) launched a thematic group on ‘Complexity and Planning’. Until that time, ‘complexity’ had been seen by the wider community as ‘exotic’, ‘freaky’, ‘fuzzy’ and ‘out of touch with contemporary planning’. Nevertheless, there was plenty of support at the event. More importantly, some of the support came from those leading the mainstream debate, which was very much focused on the communicative rationale. Over the years, the issue of complexity developed further within Aesop, and it quickly became an attractor in its own right: complexity has been the second-most popular theme at Aesop’s conferences for several years in a row. However, this does not mean that ‘complexity’, as a non-linear concept, has been widely understood by everyone. Numerous planners still consider complexity as synonymous with ‘complicated’, with some labelling the most daunting planning issues as ‘too complex’ to handle. Thus, it remains a challenge to essentially link the planning debate with the Complexity Sciences.

8. Systems theory bridging planning and complexity

De Roo (1999) and Zuidema (2014) saw Kauffman’s (1990) differentiated view on systems as a possible bridge, with the latter differentiating between traditional systems (which Kauffman called ‘static’) and dynamic systems. As we mentioned above, in line with Kauffman’s reasoning, De Roo and Zuidema proposed the division of contemporary planning issues into various degrees of complexity, resulting in categories which match Class I systems (closed systems representing blueprint planning), Class II systems (circular feedback systems representing scenario planning) and Class III systems (open network systems representing collaborative and participative planning). Class I to III systems are all static, a-temporal and traditional systems. Kauffman added Class IV systems, which were ‘complex adaptive systems’; considered to be dynamic and as progressing non-linearly through time.

There is much to say in favour of Class I, II and III systems not being seen as completely distinct from Class IV systems but as differentiated kinds of the latter (De Roo, 2010a: 33; see Figure 1C). While Class I, II and III systems are considered to be static, fixed and frozen in time, perceived as they are in the here and now, these classes – and the planning issues they represent: straightforward, complex and highly complex in terms of 'static complexity' – will become *transformative* the moment time is included: they will behave as Class IV systems. To survive, these Class IV systems, or 'complex adaptive systems', must interact with, adapt to and coevolve with their environment.

What are now referred to as Class I to Class IV systems were already of interest to the mathematician Warren Weaver in 1948 (1894–1978). Based on probability theory and statistics, he made a distinction between 'simple problems', 'disorganized complexity' and 'organized complexity'. He considered the 'simple problems' to be straightforward and predictable issues. 'Disorganized complexity' related more to multiple connected issues (networks) to be dealt with on the basis of statistics. 'Organized complexity' relates rather well to what we have called 'complex adaptive systems'. It was Weaver's work that inspired Herbert Simon (1962) to state that organized complexity was complexity with an architecture. This is more or less what this contribution intends to generate, while addressing the conditions of transformative change.

The interdependence of the system and its contextual environment has consequences. These not only depend on the open state of the system, but also on the dynamics of the contextual environment, which will vary from placid to turbulent (Emery and Trist, 1965). Moreover, such consequences will also depend on the flow of energy, matter and information between environment and system. In other words, the context matters and is often – if not always – crucial when addressing transformative change.

Therefore, in addition to the traditional scientific focus on the parts of the whole and the exclusion of time, a new kind of science is emerging, with an eye on non-linear developments, to which contextual behaviour and time are relevant (Pagels, 1988; Wolfram, 2002). Reductionism (the whole can be understood through its parts) is facing serious competition from holism (the whole is more than the mere sum of its parts) and expansionism (the whole obtains its meaning through interaction with its environment and is context dependent). Moreover, with expansionism, time and non-linearity can no longer be ignored.

The system and its environment may have an interdependent relationship that varies from being relatively stable to moments of excessive instability. In particular, in moments of instability, a break or disruption can occur, which may force the system to adjust and to settle again in a new but relatively stable state. Consider the flow of traffic on a motorway. This flow is often altered if not disrupted in the acceleration lanes, due to cars jockeying for position in the flow. This instability or mismatch can easily result in traffic jams and traffic congestion which dynamically resonates through the chain of cars. This can be seen as a symmetry break within the system, after which the system exhibits adjusting behaviour, known as 'self-organization' (De Roo, 2016). The traffic example concerns a system which is internally affected and adjusts without undergoing a transformation.

Nicolis and Prigogine (1977) go a step further in their explanation of how a system may encounter a disturbance, a constraining factor, followed by a non-linear and therefore uncertain period during which the system adapts and changes, before stabilizing again: this is called bifurcation. In such a situation, the system not only adjusts but also transforms, structurally and functionally. A constraining factor, for example, might be measures to ban cars from the city centre. This will be followed by adaptive behaviour from the various actors involved, which could lead to an increase in cyclists, for example, or in more outdoor cafe terraces and a change in inner-city functions.

The interdependence of system and environment is multilevel in character. This means that a complex adaptive system is a part of a larger system. At the same time, the system represents an entire set of subsystems. It is not only this interdependence between super-systems (macro level), systems and subsystems (micro level) that is relevant. The interdependence of system and environment is also known for the complex adaptive system having a peculiar but relevant dual characteristic: it is both flexible and robust. While this dual relationship is seemingly an internal affair, it enables the system to adapt to a contextually changing and turbulent environment (dynamics), while remaining a coherent whole (robustness) (Cilliers, 1998). Further below, more details of this dual character of complex adaptive systems will become visible, which allows these systems to float at the edge of order (uniformity) and chaos (diversity) (see Figure 1B & C). The result is an alternative understanding of what a system might be, how it behaves and how it adapts and transforms (Waldrop, 1992; Holland, 1995). Class IV systems and their behaviour differ in various ways from the traditional Classes I to III systems.

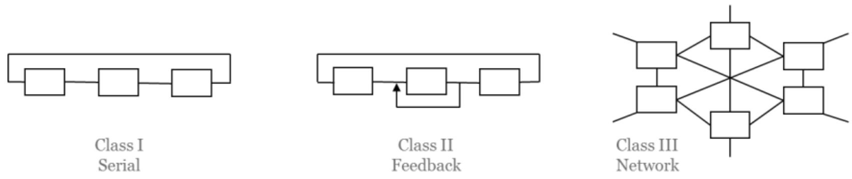


Figure 1A: Traditional classes of systems with nodes and interactions ranging from closed (serial) to open (network) systems

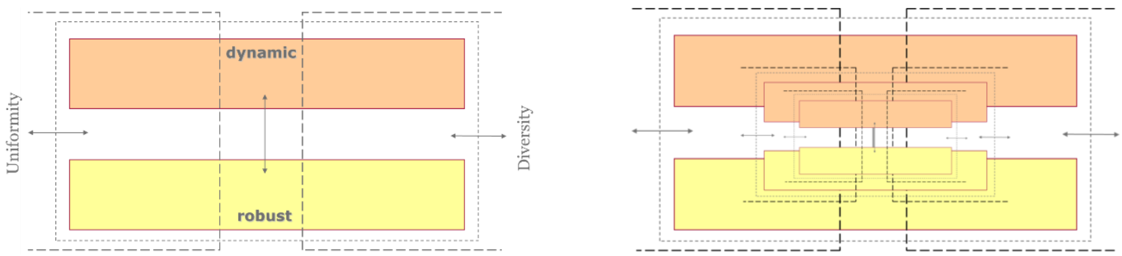


Figure 1B: Class IV system: Complex adaptive system with internal interaction between a robust and dynamic layer, and positioned between external environments of order (uniformity) and chaos (diversity), in singular form (left) and in a multi-level constellation (right) (De Roo, 2015)

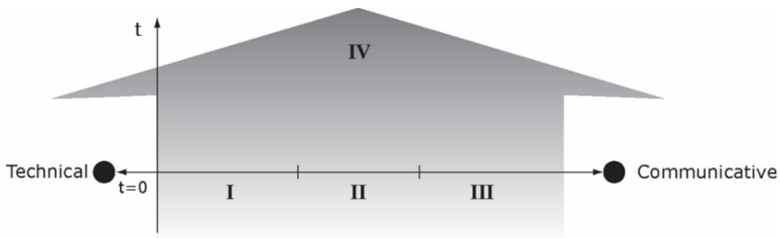


Figure 1C: Issues in planning positioned between the technical (certainty) and the communicative (uncertainty) extremes to planning, differentiated according to 'degrees of complexity' based on Class I to III systems, but to be seen as types of Class IV systems (De Roo, 2010a: 33)

Traditionally, systems are seen as a collection of nodes interacting internally (closed system, often represented by nodes, serially positioned and operating as coordinative elements) or externally (open system, often representing a temporal and informal network of actors). The former is a system that is represented by its parts, while the latter system exhibits, in particular, a relationship with its context (Figure 1A; Von Bertalanffy, 1968). However, these traditional systems are best at presenting a situation as it 'is', the state of the art at one particular level of existence, with nodes as parts of a cluster whose interactions differ (in character and/or intensity) from those which are part of the cluster's context.

A complex adaptive system, or a Class IV system (Figure 1B), is imagined as something entirely different: not just an open system, inseparably connected with its context, but as well in a 'transformative' state. The system consists of subsystems and is also part of and connected to a wider environment made up of systems. It is also open to change and is transformative in character (Figure 1B; Cilliers, 1998). Consider a city as a complex adaptive system, with its neighbourhoods as its subsystems, and the region in which the city is located, as well as the network of cities to which it is connected, as its context. Such a system is therefore connected to various levels of scale. The system owes its existence to its sub- and super-systems. In other words, the system is connected with other, neighbouring systems in the immediate vicinity, with macro systems at higher levels and with micro systems at lower levels. These systems are dissipative, continuously exchanging and sharing energy, matter and information with each other, through which they relate, respond and adjust to each other.

Complex adaptive systems must be viewed as part of an environment which is intrinsically unstable and in flow, on their way to achieving a more stable position, which will never be reached absolutely, as it conjuncts with its environment being 'out-of-equilibrium' (Cilliers, 1998). This prevents these systems from withering and receding into order, uniformity, persistent stability or a 'dead' environment. Alternatively, it could be said to prevent systems from collapsing into ultimate and destructive chaos. Instead, these systems adapt to external situations, self-organize internally, coevolve structurally and functionally, and transform in such a way that a new temporal internal and external balance are attained. What this balance will entail will be a serious point of discussion in the second half of this contribution.

While 'out-of-equilibrium' the system will alternate between periods of stability (temporal persistence) and instability (dynamics), which strongly depends on contextual interference at a particular time and place. Clearly, this is different from a view of a system of nodes and interactions with a fixed identity and persistence in structure and function.

The ordering principle – so much the focus of planners – would then no longer be a ‘static’ order, or a permanent match between structure and function, or symmetry enforced and sustained through regulatory measures. However, this does not mean that such an enforced order is no longer relevant. In various situations it still is relevant, for example, in the case of road infrastructure, which has to be reliable and predictable to support one of the most profound functions of the physical environment: its accessibility. Another example concerns environmentally intrusive functions (industry and traffic) and the desire to keep these distant from sensitive functions (housing), which is enforced by environmental zoning. Despite these examples, the focus, so often solely directed to enforced interventions on functions within space, might be extended to an awareness of autonomous change and transformation, which is also intrinsic to systems and their contextual environment (De Roo & Silva, 2010; De Roo, Hillier & Van Wezemael, 2012). In this case, the Complexity Sciences would be an example and an asset, having gone to great lengths to understand how this non-linear, transformative change might happen, what this change will lead to and what this tells us in the abstract (Pagels, 1988).

9. Patterns, breaks and the interdependence of spontaneous and intentional change

This transformative change is more than a Newtonian response in the form of action or reaction in isolation, and a repositioning of some object, body, node or entity. At various levels, multiple systems can be observed interacting in such a way that dynamic patterns emerge (Allen, 2016; Hayek, 1967). At the macro level, these are sometimes called ‘trends’. These trends or patterns are not stable and endlessly sustained, but persist temporarily. The individual system endeavouring to fit with its contextual environment, transforms due to adaptive and self-organizing processes, while also deviating according to such trends or patterns. While various systems independently from and autonomously of other systems make their moves, unintentionally all together they increase the incidence of these trends.

The interdependence of systems and their environment is again at stake. While systems are transforming, seeking a new balance and a good fit with their environment, this contributes to the progression (and decline) of dynamic patterns, as a temporal manifestation of stability to which systems are attracted. What we are looking to find here are the ordering principles which 'condition' this transformation of systems in relation to their environments. Moreover, by considering these environments, the materialization of dynamic patterns are also relevant. In this paper such transformative interdependences will be considered in relation to human settlements. However, first a bit of history.

Alan Turing (1912-1954) made a now famous point (1952) about how dynamic patterns of attraction might emerge: he needed nothing more than two homogeneously distributed substances with different characteristics – one 'locally activated' and the other with 'long-range inhibition' – to meet and mix, producing gradients, shapes and patterns. Turing's work showed how easily a dynamic pattern can emerge. Difference with minimal variety is sufficient; for example, when water and air collide, the patterns which result are known as waves. Not even asymmetry – for example a rock in a river resulting in turbulence – is needed for patterns to emerge.

Perhaps somewhat surprising, but thermodynamics, the weather, population dynamics, cities and urban development are all representations of the same type of system, and are all behaving in the same way: as non-linear dynamic or complex adaptive systems. Complex adaptive systems are not commanded through direct causal relations based on universal laws, but respond to them, in the sense that these universal laws represent patterns to which systems tend to drift towards. Clearly, not only universal laws are relevant. Complex adaptive systems also respond to local conventions. This is particularly the case in biosphere environments – where matter, energy and information conjoin to evolve into living creatures – and all that they entail: ecological, social and economic networks, and socio-spatial structures ranging from termite hills (Turner, 2000) to urban agglomerations (Batty, 2005; Yamu & Frankhauser, 2015). Thermodynamics, the weather, termite hills and population dynamics, cities and urban development, all represent complex adaptive systems and processes of situational change. However, only the latter, cities and urban development, are open to intersubjective reasoning and anticipative behaviour, and as such relate to social complexity.

The Complexity Sciences consider such asymmetry – or a symmetry break, a tension or a mismatch – the more obvious instigator of transformative change (Kelso, 1995). This may be due to shocks and disaster – Aleppo in the Syrian war, Detroit suffering from a declining manufacturing industry – or due to small mismatches, for example neighbourhoods in need of regeneration, or the seasonal pressure of tourism in cities. In all these situations, it is the symmetry break that leads to a response, through which the system adapts.

In the traditional view, a break is considered synonymous with the 'problem' to be brought under control. In the alternative and non-linear view, a break is not considered something that should disappear or be removed, but is seen as the possibility of something new emerging. To put it bluntly, in a healthy state, both the system and its environment are always ready for change, which is likely to occur due to cracks emerging. For example, the transition from fossil fuels to renewables is, by and large, a consequence of geopolitical tensions and a sudden and frightening rise in average temperatures and sea level (Stremke & Van den Dobbelsteen, 2012). The response is a desire for alternative and more sustainable policies and a transformative process, which includes dismantling coal-fired energy plants and the emergence of solar cells, wind turbines, thermal heat and biomass. Consequently, there will be a transformation of generic fossil energy strategies and international energy networks into situational approaches and location-specific constellations.

What is happening is not just a spontaneous response to a symmetry break followed by an energy transition, but also includes intended actions anticipating an expected energy transition. Expectations and the desire to respond to the negative consequences of fossil-fuel energy use are triggering intentional policy and purposeful interventions. Policy in support of an alternative energy system is anticipative and preventive. It is anticipating a likely energy transformation and preventing the situation from becoming worse with regard to CO_2 production, climate change and sea-level rise. In other words, processes of autonomous change cannot easily be seen as independent from intentional policy and purposeful interventions. Policy and planning are responsive to and anticipate expectations.

This interdependence of autonomous change and anticipating behaviour is very much part of everyday practices. Already mentioned in this respect is the planner designing a neighbourhood in anticipation of demographic development. Also mentioned was the policy to restrict cars in inner cities, in response to increasing pollution and congestion, which may trigger all kinds of local development, such as an increase in cyclists and outdoor terraces (Newman and Kenworthy, 1999). Another example is the rise in popularity of the e-bike (a macro trend), which may lead at some point to the development of alternative bike routes (locally created) – speed lanes for bikes – as well as more people from the periphery considering cycling as an alternative to the car to go to town and work, which is likely to become a newly emerging macro development.

Sometimes expected change is taken for granted. Consider, for example, the development of a hypermarket or outlet centre just outside a city. This development occurs as a break, which will trigger local change, with increasing numbers of people being able to do all their shopping in one go, or to do their shopping more cheaply; however, there is a possibility that the city centre will be pushed into a downward spiral of decline (Kraas et al., 2012). Purposeful actions and interventions can put a chain of events in motion which generates unintended change and subsequent development. At the same time, spontaneous and autonomous change can trigger intended action. In other words, purposeful actions and autonomous change cannot always be seen as independent from each other.

This is a relevant message for the discipline of spatial planning, just as it is for the field of social complexity. Moreover, it should be noted that there is a difference between a system's 'healthy state', responding to change whatever the outcome, and the normative understanding of this outcome as 'good'. In neutral terms, systems respond to, relate with or become part of patterns as a consequence of the change that is occurring. In this respect, it does not matter much if change is the consequence of spontaneous transformation or intended action. However, humans will evaluate this change in a system and the various patterns emerging as good or bad. This will trigger new intentions, decision-making, planning and policy to guide actions. However, people also want a say about any change that might happen, and whether it is appreciated or not. Moreover, when it is not appreciated, they want to have the opportunity to intervene and adjust the outcomes if necessary.

10. Towards conditions for change

A symmetry break, disruption, mismatch or tension can result in patterns at various levels affecting the system and the system's environment. The individual system will conform to this disruptive change if possible, by adapting and seeking a 'good' fit internally and externally once again. It will go through an internal process of self-organization (De Roo, 2016a) and an external process of adaptation. In the words of Giddens (1986: 118-119), 'this refers to the use of space to provide the setting for interaction, this setting of interaction in turn being essential to specifying contextuality'. The result may be a fundamental transformation of the system in terms of structure and function.

In situations in which the contextual environment is relatively stable, the system will seek ways to maintain its identity, its functioning, its structure and its purpose, while nevertheless coevolving and transforming into something different. This is a process of *slow transformation*, which allows anticipative behaviour and intentional adjustments with a focus on what the system might materialize into and what the consequences might be. The system will progress (meant as transformative steps in time, including a retreat) in a self-evident way, maintaining a balanced mix of *transformative conditions*. These conditions are *contingently related* to each other, coupling structure and function, and as such determine the transformative space to which the system conforms. To be precise: *contingent transformative conditions*.

Processes of slow transformation can enter into a disruptive state of turbulence when perturbations from the environment push the system off track. Such momentum for change is known as a symmetry-breaking *bifurcation* (Buescu et al., 2003). The movement which follows is again most likely to entail a process of coevolution, a mechanism which allows the system to adapt to its turbulent environment. The conditions under which the system transforms are called *adaptive transformative conditions*, which become relevant in moments of sudden, spontaneous transformation. However, such a process of coevolution and adaptation is no longer self-evident and has limited anticipative power, with the system's structure and function transforming through combined and interdependent interactions into something unknown. This also includes the system's new position within its contextual environment, in which it has a new role to play. Both the contingent and adaptive transformative conditions will be explained in depth further below.

Generally speaking, transformative conditions concern the local implications of physical laws, biological rules or instructions and social conventions (and in the near future digital algorithms which condition the virtual) to which systems and their environment respond and which determine their behaviour. The question that arises here is how to identify the conditions that are specifically relevant; those to which non-linear dynamic and complex adaptive systems respond.

This paper began with a discussion of evolution and revolution, through which the relevance of transformative behaviour in the world of which we are part was emphasized. Evolution relates to some extent to slow transformation, while revolution can be seen as a sudden transformation due to turbulence. Whether the transformation is slow or sudden, a revolutionary or an evolutionary process, in all cases it is likely that the system's structure and function will transform together, in conjunction with each other, seeking internal stability, a healthy state and a good fit, while developing a new relationship with the contextual environment: the system will coevolve.

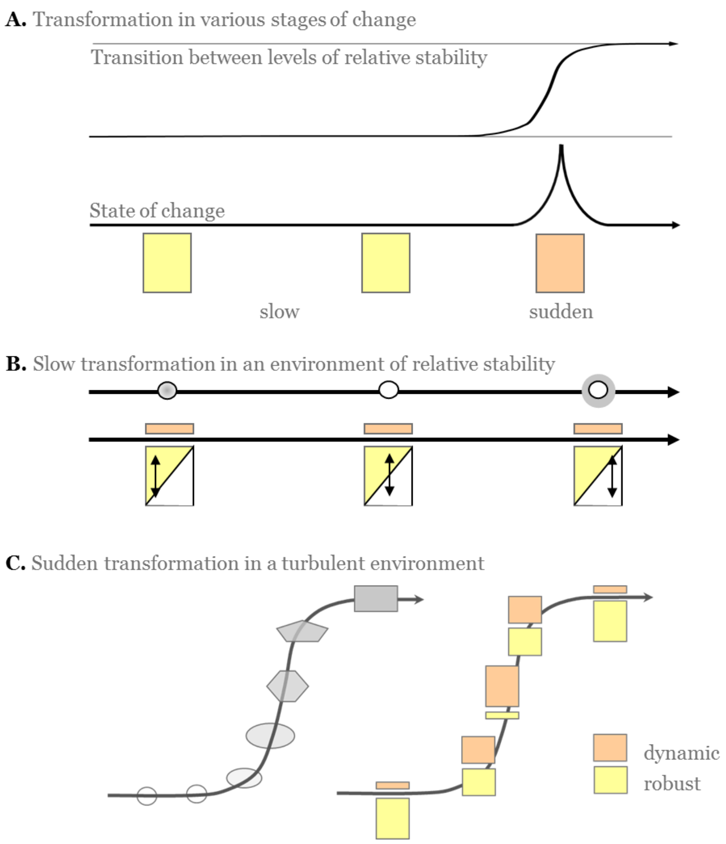


Figure 2A: System behaviour at stages of slow and sudden transformative change

Figure 2B: The system can coevolve from a stand-alone and straightforward situation into an integrated whole embedded in a contextual environment (Arrows: Figures 3, 4, 10 and 11)

Figure 2C: Left: Coevolving structure (circle to square) and function (white to grey) going through a transition from one stable phase to another looking for a 'good' fit. Right: While coevolving, the robustness of the complex adaptive system will first decrease, with increasing dynamics, until a 'good' fit with the environment brings back stability (De Roo, 2012)

Again, the fossil-fuel energy system offers a good example (Noordman & De Roo, 2011): a transformation from continentally arranged energy networks towards local energy landscapes. Continental networks connect huge energy plants with the individual consumer (structure), ensuring the delivery of 220V electricity (function), no matter where the consumer is located (structure); however, CO_2 is an unavoidable by-product (dysfunction) of such a system. In contrast, local and tailor-made energy landscapes could emerge as a consequence of local and situation-specific possibilities (enabling conditions) and difficulties (constraining conditions). In addition to electricity generated from solar cells and wind turbines, local energy landscapes may include heat grids and biogas systems (structure). For the heat grids, the traditional concept of producer and consumer may be replaced with the 'prosumer' (Steg et al., 2015): where every energy user (function: heat embodied in steam or hot and warm water) passes the energy carrier (structure: water) on to the next user, and therefore becomes both a consumer and producer, hence prosumer (function). Consequently, the energy system would change its composition (structure) as well as its identity (function), meaning the system has coevolved, and the situation and its structure and function have fundamentally changed (Figure 2).

The energy transition is perhaps a slightly tricky example, as it is only partially a transformative process that has emerged autonomously and spontaneously. It is also an anticipated trajectory, with expectations that a transition will indeed take place, must take place, and which is considered desirable by most. The consequences of maintaining the status quo are not appreciated, given climate change, sea-level rise and geopolitical tensions, to name a few undesired outcomes. The circumstances are such that there is a mixture of possible alternatives (‘renewables’) as well as the necessity to transform the system. At the very best, one could speak of a hybrid situation, with a mix of regulating and induced conditions alongside transformative conditions which could trigger change. Various parties are still very much dependent on and invested in traditional energy systems. Therefore, what these energy systems will change into remains uncertain. It is likely there will be a merger between the traditional and generic energy grids and local energy sources, creating (at least for a while) an energy landscape consisting of two parallel and independently functioning networks (Figure 7). Alternatively, the traditional and generic network might be replaced entirely by local energy production; or something completely different could emerge, perhaps an energy-driven society based on hydrogen, ethanol or nuclear fusion.

Although the transformative world of energy is thus not solely governed by spontaneous change but also by anticipatory actions, the reality presented varies, with stages of non-linear change within which the energy system coevolves. Expectations of non-linear change create a situation that differs from that which planners and policymakers are used to: a result which varies from a situation which allows anticipatory behaviour to a situation which is unpredictable ‘a priori’. This is a consequence of slow and sudden transformations, which are alternatives to a ‘predefined outcome’. Instead, these transformations contribute to ‘undefined becoming’ (Boelens & De Roo, 2014).

11. Transformative behaviour of settling societies

Acknowledging a world in a state of undefined becoming is not the end of the story, nor does it leave us empty handed, as there is so much to hold on to. Though this view differs substantially from a traditional perspective, with science focusing on isolated entities, systems and situations, taking the parts out of which these are composed into consideration. This is helpful in understanding these entities, systems and situations as they ‘are’, and supports understanding their structures and functions, as well as content and processes at a particular place and time (Prigogine, 1980). This reductionist approach produced universal laws in physics and chemistry. However, it overlooked an understanding of entities, systems and situations as positioned in an environment which is itself contextually embedded, ‘out-of-equilibrium’, open and transformative. This means a change in perspective is needed.

If there is one particular issue open to autonomous and discontinuous change that is of interest to planners, it will be the trajectory through which settlements coevolved towards larger entities, and out of which the urban has emerged – from the first prehistoric huts grouped together to modern urban life and the global dominance of the city. This is a trajectory that can be understood and that makes sense as a non-linear trajectory of change; a trajectory that has gone on for ages and has brought us the urban environment we are so used to today. In this respect, Van der Leeuw (2009), an archaeologist by origin, made a serious attempt to construct a non-linear perspective to elaborate on how humans created spatially compact and socialized environments for themselves. He called his attempt ‘the archaeology of innovation’, which includes two central elements. The first is the ‘dissipative’ idea that humans absorb energy from their environment to organize and socialize, ensuring a shared capacity for information processing, an activity out of which societies emerge.

The second essential element is the *intersubjective response* by society in the process of transformation of settlements. This ‘intersubjective’ side to the story is relevant and has consequences. Firstly, it allows a linkage with the debate in planning theory, in particular, the communicative side of this debate and its focus on intersubjective reasoning and agreed realities. The intersubjective introduces values rather than facts, the sharing of meanings rather than definite conclusions, various perspectives rather than a single and exclusive truth.

In addition to and in conjunction with a factual, object oriented world, a world of values, meanings, perspectives and agreed realities was thus brought to the stage. Both are fundamental to humans, their behaviour, attitude and actions, and the artefacts they produce. Facts are nothing without values. Every object or situation humans observe is automatically projected with a meaning. Therefore, understanding a human reality builds on two pillars: *object orientation* (observation of a factual reality understood by a technical rationale) and *intersubjective reasoning* (participative interaction towards an agreed reality understood by a communicative rationale).

Geddes (1915), Christensen (1985) and most, if not all, spatial planners saw complexity in relation to the material impact of spatial change, with a factual and object orientation predominant. The communicative turn in planning that took place in the 1990s made a connection with intersubjectivity. Intersubjective reasoning and interaction produce ideas and opinions that merge into shared values, meanings and understandings about what is collectively perceived and thought (Hillier, 1999). As intersubjectivity is one of the pillars in understanding human reality, it should play a role in and be a part of the understanding of transformative change, non-linearity and the world of emerging patterns.

This could be explored even further, in the direction of implicitly perceived patterns within cultural and psychological domains to which individuals and collectives relate. Deleuze and Guattari (1980), for example, perceived the world as constituted by assemblages, a set of attributes and codes (DeLanda, 2006), or arrangements – where the situation gains meaning through the constellation of the situational relationships and through territorialization and its ordering or structuring of the situation. Massey (2005; see as well Hillier, 2001) wanted us to be aware of how space produces implicit relationships between objects and subjects. Among such relationships are emerging power relations, the production of spaces of power, a geography of power and powerful institutions (Massey, 2005). Spatial transformation is thus not only materially produced but is also the consequence of immaterial intersubjective interactions. Such geographies, arrangements and the production of spaces and places in terms of power, values and meanings are considered engaging, temporary and interacting with the material, and, therefore, also in a state of becoming (De Roo, 2010a; 2012).

While the planning debate more or less acknowledges this view, the Complexity Sciences have not yet reached this point in their debate. Even within the domain of social complexity, the intersubjective side is largely ignored, with all that is human or social considered from a material, factual and object oriented perspective (Eve, Horsfall & Lee, 1997; Innes & Booher, 2010; Luhman, 1990). Here, we take the position that *a human environment has to be seen not only from an object oriented perspective but also in conjunction with intersubjective reasoning*.

Collective behaviour, and collective choice and decision-making, involve intersubjective reasoning almost by definition. This is considered an essential position for the discipline of planning, as well as for social complexity. Here, complexity and non-linearity are seen in the light of action and shared meanings, and social complexity is therefore defined as a merger of and a transformative process between object orientation and intersubjectivity (see Figures 4 & 10). It is from this point of view that the transformative conditions through which settlements progress through time will be identified and defined (see Figure 3).

In the distant past, humans had no alternative other than to adapt to the conditions they were confronted with, taking resources (matter and energy) from their physical environment (Figure 3: resource oriented triangle) to keep themselves alive until these ran out, after which they would have to move on. According to Van der Leeuw (2009), 70,000 years ago, humans started living together in increasingly larger groups, which was conducive to sharing information, a collective memory, as well as a seasonal understanding and territorial organization. Around 10,000 BC, these groups further increased in size and started living together in settlements. As such these settling societies began to cultivate the physical environment. This meant that they started investing in their environment, securing a living in an organized manner, depending on each other, reducing the nature-related risks and working on increasing their energy production capacity (see Figure 3).

As settlements and settling societies grew, Van der Leeuw argues, social conventions became increasingly relevant, ensuring people could live together decently, responsibly and in support of each other. Societal problems increased, and institutional responses were needed to resolve them. Institutional arrangements not only enabled life in settlements, as their organizational power began to extend to the wider environment (Figure 3: collective oriented triangle). This was essential, as the difficulty of extracting energy from the environment can act as a serious constraining factor (see Figure 3: the move from left to right within the resource oriented triangle).

The growth of individual settlements was constrained due to limited natural resources, however it stimulated the emergence of clusters of settlements. A new balance was found between the dispersion of settlements to maintain their energy production capacity, and the information-sharing capacity created by increasing numbers of different groups interacting (Figure 3: the right side of the collective oriented triangle). These clusters of settlements and their institutional design required the construction of infrastructure, which was encouraged to ensure access to resources.

With clusters of settlements a rapidly emerging world of social conditions began to exhibit multiple layers of relevant and interdependent conventions. New conditions were needed, as well as administrative structures, including methods for keeping accounts and records. This is just one step away from the emergence of a ruling class. It also meant a shift from a ‘responding to’ to a ‘control over’ attitude, which enabled further development. Consequently, the capacity for information-sharing increased, while the footprints of settlements crossed societal borders, with energy and matter remaining the constraining factors.

Around fifteen hundred printing technology became an enabling factor to the sharing of knowledge. Knowledge became widely available about the existence of different cultures and behaviours. This resulted not only in global trade routes, but also in competing markets and monetized urban developments. Information-sharing increased further, which led to the emergence of a global economic system and to a civil society, which at some point (such as the French Revolution in 1789) stood up for its rights and for better living conditions.

The nineteenth century fundamentally altered urban life, with an energy revolution, an industrial revolution and technical and scientific revolutions. Thinking outside the box made innovation endemic. To begin with, conditions for labourers, which did not leave them the time and money to consume, had to be acknowledged as a severe constraint. Conditions were no longer merely functional. They became ethical as well: the consequences of actions, behaviour and interference also had to be seen from a moral point of view.

The moment this economic imbalance in society was addressed, halfway through the industrial revolution, allowing labourers time to enjoy life and consume their earnings, a chain of rapid changes in economic prosperity, social behaviour and cultural attitudes led to what our world is today – a global village with time and space rapidly shrinking, worldwide urbanization, schools as institutionalized modes of knowledge-sharing, surpluses being created from a multitude of sources, including a huge increase in personal possessions and life expectancy, and an unprecedented change in information-sharing due to the rise of the digital and the virtual era.

The twentieth century was a period of fundamental, transformative change. This era generated a variety of new conditions which triggered various transformations in institutional design. However, these transformations were generated within a realm which was dominated by a one-sided orientation towards functionality and economic value. This led to a narrow interpretation of our values and a limited focus on contextual influences, due to which humankind struggles (often happily) from one crisis to the next.

Some might believe that crises should be avoided, but crises are also events which are quite ‘natural’ in a world which is non-linear and dynamic. These crises are part of life. Crises can be viewed as symmetry breaks, mismatches and frictions, which are essential for triggering non-linear change, and can result in the emergence of new patterns (Hayek, 1967; Nagel, 1962).

The twentieth century and its way of reasoning was strongly object oriented, although the social domain, anticipatory behaviour and intersubjective reasoning have always implicitly been around. The point about the non-linear aspects driving change, with new patterns emerging, is these should no longer be understood solely through object orientation, as we have argued, the intersubjective side matters as well.

12. Modelling the conditioning of transformative change

Central to this understanding of social complexity is the idea that the transformative process behind settlements and societal evolution requires a balance between the capacity to gain access to energy resources and the capacity to generate collective action within communities, leading to the intelligent exploitation and management of the energy available. Energy becomes available through the processing of matter on the basis of experience and information-sharing. Actors organize themselves to optimize the sharing of information and to enhance their capacity to generate energy: this is a settling society in action. As actors become organized into collectives and contribute to wider society, learning processes begin to become effective. In this respect, information is experience shared among many actors. This reasoning and understanding, partially deduced from Van der Leeuw’s ‘archaeology of innovation’, is summarized in a comprehensive model framing *transformative space* in Figure 3.

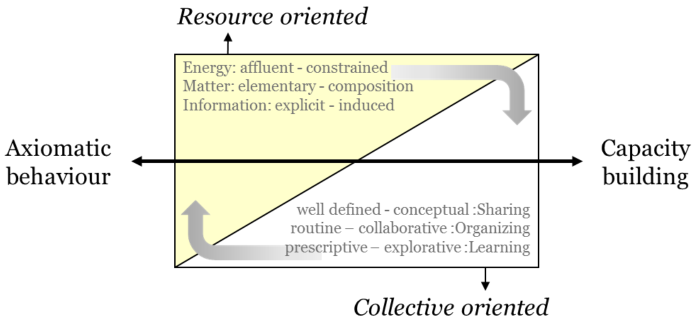


Figure 3: A transformative model of settling societies (The elementary set up: see Figure 4)

Figure 3 shows the interdependence of collectives and their resources, oscillating between two extremes of behaviour – the routines of axiomatic behaviour and the struggle to build capacity as a collective action. Figure 3 is also an abstract representation of processes of transformation (Figure 4) made concrete for settlement development, which – of course – is a consequence of collective action. In this sense, Figure 3 presents a transformative model which represents a circular and iterative trajectory of sharing of energy, matter and information. It is a trajectory which is not only circular but also *contingency related*. This trajectory, representing a contingent relationship between energy, matter and information, on the one hand, and sharing, organizing and learning on the other, is relevant to settlement development. However, what matters even more is the ability to see how these are organized and related to each other.

The figure reveals that this sharing requires collectives – a settling society – to organize, which enables them to learn from the difficulties encountered. This process is not simply about the 'logistics' of matter, energy and information. It also includes valuing and anticipating situations, resulting in adaptive and innovative behaviour of collectives based on sharing, organizing and learning capabilities. This 'collective oriented' process is a process of intersubjective interaction which feeds the processing of energy, matter and information: *intersubjectivity* in conjunction with an object oriented or 'resource oriented' perspective.

On the left, ‘resource oriented’ side of Figure 3, information can make explicit how matter is regarded and treated as a source of energy. This information is generated from lessons learned and is deduced from experience, but probably contains more than merely practical knowledge. It may well include deeper knowledge, in the sense that the ‘rücksichtslos’ exploitation of the environment would create an unsustainable basis for the survival of society. Humans are capable of anticipation, and when the circular or iterative route of development is confronted with a break, mismatch, crisis or barrier, society’s response is to innovate. This could lead to many different actions, all intended to secure or increase the capacity to access energy, which in turn generates all kinds of new information. If this is successfully done, society can evolve to enjoy a higher standard of living as a whole (see Figure 5), while failure will result in lower living standards. Whatever the direction followed, it will affect the settling society, society’s settlements and their living environments.

Figure 3 not only encapsulates Van der Leeuw’s reasoning about settlements evolving through the ages, but also models the evolutionary, transformative trajectory of a settling society through time. This transformative trajectory is initially circular. Consequently, a settling society is one that evolves in a circular pattern. At a point on the upper left of the circular trajectory, society is confident in using resources which might seem to be available without limitations. However, at some point – further towards the upper right – there will be an increase in constraints, thus restraining the use of the resources necessary to keep settlements going. This will push settlements to progress further along the circular path. This trajectory desires and requires the growing input of ideas and suggestions from society to make use of resources in smarter ways: society innovates and becomes increasingly ‘more complex’. Rather than routine-like behaviour, new scenarios will have to be considered and, subsequently, situation-dependent approaches become relevant. These approaches will result in tailor-made strategies, integrated solutions and specialized protocols, with the emphasis shifting towards communal capacity building.

At the upper right in the circular trajectory, most if not all options have been explored, and there is one certainty remaining: the path taken so far is no longer sustainable. Uncertainty about how to continue making use of resources is high, and the integrated and situation-specific approaches are barely capable of producing the desired resources. Nevertheless, these situational approaches could become new sources of creativity. While hidden and yet to be discovered, it is likely these approaches contain information about alternative routes towards the future.

At some point a shift in focus from 'resource orientation' to a 'collective orientation' is likely to take place, as it is up to the collective to become a source of inspiration and to value the constraints of uncertainty as a source of creativity. The challenge is to find convincing alternatives, about which consensus has to be reached within the collective or within society. At this point, it is likely that a substantial transformation will be occurring, perhaps even towards an entirely new level of existence.

It is evident that a 'factual reality' is, at some point, replaced by ideas about how reality could work for a settlement to survive. The 'agreed reality' gains the upper hand, driven by the need for alternatives and innovation. Schumpeter (1942) labelled this a period of creative destruction, in which outdated products are replaced by new ones. He considered this 'process of industrial mutation' to be essential within systems of capitalism. In the evolution of settlements and settling society, this would not be very different: the commonly accepted frame of reference has to be deconstructed and reconstructed to allow alternatives a chance to prove themselves. If they are appreciated and feed confidence, a new frame of reference can be constructed.

This reconstruction of a new reality that works entails a move from right to left along the circular path, passing through the collective oriented triangle of the model (Figure 3). It is a process in which a collective agreement to be creative will result in products which are appreciated and commonly understood. At this point, certainties are considered real: a new factual reality is in the making: Shared subjectivity is perceived as objectivity. If so, another shift will take place, this time away from the collective's intersubjective reasoning and back to an orientation towards and exploitation of resources. We have come full circle.

Van der Leeuw's reflection on the history of settlements presents a sequence of such circular trajectories, resulting in the long-term, discontinuous growth of settlements. This circular progression is nothing but a contingent relationship, here between 'axiomatic behaviour', as the one extreme representing a factual reality, and 'capacity building' as the other extreme, giving expression to the desire to reach an agreed reality. This circular trajectory through time has produced a reality which today is called 'the urban'.

13. The contingent character of transformative conditions

Figure 3 presents transformative conditions to which human settlements respond in a contingent way. It presents human settlements as complex adaptive systems which undergo transformation in a conditioned environment and exhibit conditioned behaviour, which is the consequence of *contingent transformative conditions*. This is quite significant, as contingent behaviour comes with *explanatory power*.

Contingency dictates and gives expression to a transformation of a system with a *dual character*. Any system with structure and function has such a dual character: it is about *coupling* of structure and function. In the abstract, one might see situation ‘a-1’ transforming into situation ‘z-9’, with the structure represented by letters and the function by numbers. Or consider a white circle transforming into a grey square, as proposed in Figure 1. The trick is to see that the variables are not random but given (or generated somehow) and relational. Contingent behaviour produced by transformative conditions can result in information about the system’s trajectory of change ‘a priori’.

The contingent character of transformative conditions finds expression in the interconnected relationship between the conditions’ variables at the various points along the spectrum. At every point on the spectrum, a condition will be represented by a variable or value that is relevant at that particular point and dependent on the condition’s transformative range. In Figure 3, the condition of ‘Energy’ has been given the range from ‘affluent’ to ‘constrained’. The condition of ‘Matter’ has a range from ‘elementary’ to ‘composition’, and so on. A shift along the spectrum means the system has progressed (a transformative step in time) and the situation has changed. For the system to stay healthy, every new position taken by the system requires the reorganization of an interconnected set of variables representing conditions in a contingent way, so that these ‘work’ at this new position on the spectrum. This means that a shift along the spectrum will result in transformative behaviour of the system which is in accordance with and a consequence of the variables produced by the conditions.

These contingent conditions and the variables these produce are relevant to a particular position taken by the system, which is in an interdependent relationship with its environment. This resonates with Scott's description of contingency in organizational theory: 'The best way to organize depends on the nature of the environment to which the organization must relate' (1981: 89), with 'the organization' in this context being 'the system'. The system's behaviour is 'conditioned' by the contingent relationship between conditions and their variables in this interdependent connection with the system's environment.

Three conjunct transformative conditions are proposed in Figure 3 to represent 'resource orientation' in relation to energy, matter and information. In the abstract, these stand for a balanced interrelationship between content, process and context (Figure 4). Using synonymous alternatives, these categories may also be labelled function, structure and environment. With respect to organization theory, Pennings (1975) considered the notions performance, structure (of the organization) and environmental uncertainty to be relevant.

Another three conjunct transformative conditions represent 'collective orientation'. These are suggested to be sharing, organizing and learning. These three conditions are commonly understood in terms of perspectives, consensus-seeking and storylines (Figure 4). These are what is intellectually exchanged among intersubjectives or 'collectives'. At each and every position on the spectrum, these transformative conditions are interconnected, representing a balanced situation which allows the system to be healthy, temporally stable and to have a good fit.

Therefore, there is no single best way (Galbraith, 1973: 2) for the transformative system to progress along an unstable path. Whatever the situation the system is in, it will not be exact or given. This is comparable to a river system, meandering through a more or less flat landscape (relatively stable environment), creating snake-like curves and bends everywhere, while seeking its way towards the sea. These meandering patterns are nevertheless helpful in perceiving order in a chaotic world. Figure 3 presents a means to give expression to and understand these patterns, which are the product of conditions that allow systems to find balance in terms of their contingent interrelationship. Therefore, *the transformative conditions function as ordering principles which produce conditioned transformative space, within which the system transforms and progresses while seeking a good fit internally and externally, consequently representing a world in a state of becoming*.

Contingency, a concept that comes from organization theory and is explained by organization theory in relation to a world that 'is'. As this paper is attempting to give expression to a world becoming, this means there are differences between what is proposed here, and what is traditionally seen as a contingent relationship. Above all, the contingency discussed here is conditional, and not content or process related, as is commonly understood. This reasoning results in three differences to be made explicit here: (A.) its cognitive orientation; (B.) the irreversibility of the process of transformation; and (C.) there is a difference between contingency being an expression of what 'is', depending on the situation, and contingency as a condition for development and transformation, and as a determined route along which the system progresses.

A. The model has a cognitive orientation, with the spectrum reflecting our mental capacity to understand the world as it presents itself to us. The world is neither fully certain nor fully uncertain, which is a conclusion our mind produces due to a conjunction of a factual reality and an agreed reality. Zuidema (2014) considered this coproduction between object orientation and intersubjective reasoning to be a 'post-contingent' relationship. He argued that the contingency captured here differs from what is traditionally considered to be contingency: a conjunction or interdependence between various object oriented variables.
   Rather famous in this respect is contingency theory associated with organizational performance (Lawrence & Lorsch, 1967), which clarifies the relationship between a managerial hierarchy, the kind of tasks to be performed and the teams who are asked to perform them. Routine-like activities relate well with top-down managerial responsibility, through which a rather uniform work force will be coordinated. In the case of unique activities, a bottom-up structure will result in better performance, with specialist teams given the responsibility to deliver.
   There is a contingent relationship between these two extremes, but it is solely observation-driven and based on an object-object orientation. In this contribution, however, we are looking to capture contingency between object orientation and intersubjective interaction, where object oriented knowledge and intersubjective understanding have a relationship. Our thinking is open to these two paths of information, on the basis of which we mentally construct a reality.

B. The second difference is the irreversibility of the transformation that the system undergoes. A contingent relationship presents variables which vary while progressing along the spectrum. However, at various positions along the spectrum, the variables remain as they are or are more or less fixed. Going backwards would therefore mean going back to the same circumstances that have been met before: from ‘a-1’ to ‘z-9’ and then back to ‘a-1’ again. However, in a non-linear environment, the transformative model will not produce such a linear reversal. Returning to the beginning of the circle does not mean everything is back to how it was. We have moved along the circle, back to a starting point, which is enriched in a dissipative and transformative way (Figure 5B). However, it is most likely that something even more fundamental will have taken place along the way and that the system has reached another level of development (Figure 5C).
C. Probably the most relevant outcome of conceptualizing contingency within a non-linear world is that it has to be seen as a determined frame within which transformation of a system is irreversible. Along with this statement, another also becomes relevant: if the system is transforming, it will be following a more or less determined route in its progression. Contingency gives expression to differentiated situations, which range from generic to specific, with each situation having specific criteria which gave the situation its identity, depending on the circumstances or objectives. This contingent route with differentiated situations is however not necessarily reversible, which is due to contextual changes through time (Figure 5B) or to bifurcations (Figure 5C) the system might encounter. It’s a contingency determining a non-linear, transformative arena, where it is coproduced by the system-environment interdependence of the system under observation. Contingency seen in a non-linear, transformative context gives expression to a transformative process, development and progress. This means that under the given circumstances of non-linearity, contingency is to be seen as determinant of system behaviour. In other words, as long as the system is within a relatively stable environment contingency determines the system’s capacity to change.

14. Framing contingent processes of change

The transformative model itself has its history, conditioned as it is by various theoretical debates (see De Roo, 2016b). The model frames contingent processes of system change and 'defines' transformative space – the system's capacity to change – at the edge of order and chaos. In turn, this transformative space conditions a system's progress, as long as it can maintain its transformative route and its contingent relationships.

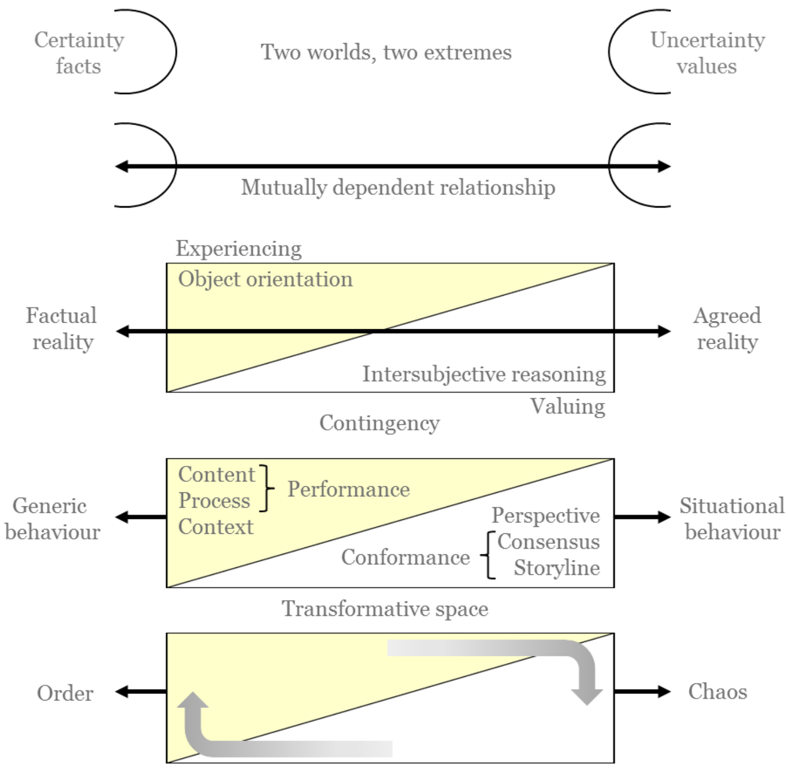


Figure 4: Building blocks for modelling transformative space allowing and determining routes for non-linear dynamic systems to progress in a contingent way (De Roo, 2016b)

The transformative model has a cognitive orientation, as it mirrors the functioning of our thinking and its capacity to grasp the world. The spectrum, therefore, represents our mental capacity to understand the world as it presents itself to us: at one end, clarity and certainty, which we claim on the basis of a *factual reality*, and at the other end, fuzziness and uncertainty, which force us to relate to each other and construct an *agreed reality*. When certainty decreases and uncertainty can no longer be ignored but is increasingly apparent, people change their attitudes to the world around them (Cialdini et al., 1990). In 1967, Lawrence and Lorsch observed the link between increasing uncertainty and environmental variety affecting internal features of the system. In the case of increasing uncertainty, the generic orientation will shift towards a situation-specific orientation, and a strong awareness of contextual interdependences. This is expressed in a shift on the spectrum from left to right: the intersubjective attitude gains the upper hand at the moment our world becomes fuzzy and our object-orientation diminishes.

What in Figure 3 was qualified as ‘resource oriented’ is in Figure 4 to be seen in general terms as the ‘object orientation’ of our senses and mind, while ‘collective oriented’ is now to be seen as ‘intersubjective interaction’. This divide between object orientation and intersubjective interaction is commonly understood as facts versus values. However, rather than see a divide, the models in Figures 3 and 4 see facts and values in concurrence, with varying ratios depending on the situation at hand – a contingent relationship.

This contingent relationship is the backbone of the transformative model and the transformative space this model produces. This *transformative space* can be found between the extremes of both ends of the spectrum and the contingent relationship this spectrum represents. Both extremes are above all mental constructs and can be understood as theoretical and non-existent in the world we perceive: our world is neither fully certain nor fully uncertain. The extremes represent environments in which complex adaptive systems will not survive.

The extreme on the left side of the model represents order: a tranquil, uniform environment with no symmetry breaks, mismatches or tension, which is a ‘dead’ environment. Figure 3 specifies this dead environment as one that produces ‘axiomatic behaviour’, with people acting as machines working routinely or intuitively to do what they have to do, not questioning why or how things might be done differently. The extreme positioned on the right side of the model stands for a turbulent, chaotic environment which would cause any system to collapse. Figure 3 considers this destructive environment in terms of community capacity, as it would leave people with little but each other to cling to. Any community will fail in such an environment if ‘developing and strengthening the skills, instincts, abilities, processes and resources that organizations and communities need to survive, adapt, and thrive in the fast-changing world’ (Philbin, 1996) proves impossible.

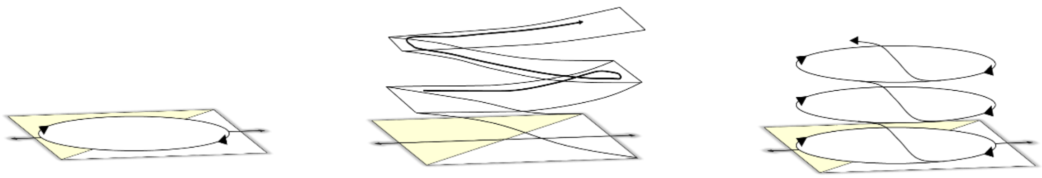
Figure 4 presents an abstract framework to make explicit transformative space and the conditions under which the settlements in Figure 3 evolve. The abstract framework builds on the cognitive potential of our mind, with its capacity to *experience* what is going on out there (object orientation: 'realism' in philosophical terms), perceived through the senses, and its capacity to *value* what is experienced (a multiplicity in subjective reasoning adding up through intersubjective interaction: 'relativism' in philosophical terms), to give meaning to what is perceived and to see a logic within reality.

Experiencing without valuing would not work for humans, while valuing without experience is simply impossible. These extremes are therefore 'unreal', they do not represent a world that exists in reality. Consequently, we could state that one extreme does not exist independently from the other and cannot function without the other. The real world exists where the two extremes meet and merge, and they exhibit a contingent and mutually dependent relationship (Figure 4).

In a mutual relationship between what we observe and what we agree upon, how we see and value what we observe, either independently from others or in a process of intersubjective interaction, results in an understanding of what we perceive and an opinion on how to act. A circular transformative process emerges out of this mutual relationship, as we have seen in Van der Leeuw's elegant explanation of how human settlements have developed through time. This circular process is acknowledged in Figure 3 and generalized in Figure 4. The point made here is: *systems are conditioned to change, with transformative conditions shaping a reality which can be experienced and perceived, and which can be made explicit in a contingent relationship* (Obviously, providing that we can decipher what these are).

These transformative processes can be perceived as cognitive shifts, which could start with an issue which stands out from its context and is easily understood, with clear causalities, progressing towards a reality which becomes increasingly dynamic, fuzzy and in need of interpretation. Unavoidably, emphasis will shift from an object orientation to intersubjective reasoning. Intersubjective interaction will be increasingly desired to come to grips with reality again. It produces a new and shared narrative, which includes lessons learned and provides fresh guidance for future actions. Again, focus shifts to the issue as it 'is' out there, with the issue again being implicitly understood: object orientation takes the lead again. At some point, these narratives are taken to be real and have become implicitly grasped by all involved. At this point, we are back at the beginning and the cycle of progression can begin again.

However, as suggested above, the issue or system does not return to the ‘exact’ point at which it started (Figure 5), as things have changed along the way. Above all, the contextual environment has changed. The issue or system has made moves along with, interdependent on and adapted to the transforming contextual environment (Figure 5B). We may call this change, growth, development, progress or decline. It is important to realize that such developments involve iterative processes, feedback loops and cycles of progression (Coveney & Highfield, 1995). These cycles of progression may entail a muddling through, but could as well slowly and steadily reach another level of existence (Figure 5B). It is also possible that the cycles of progression encounter enabling and constraining events which produce, feed and support a transition or bifurcation (Figure 5C). This, consequently, gives expression to the transformative process and the changes occurring somewhere along the circular path.



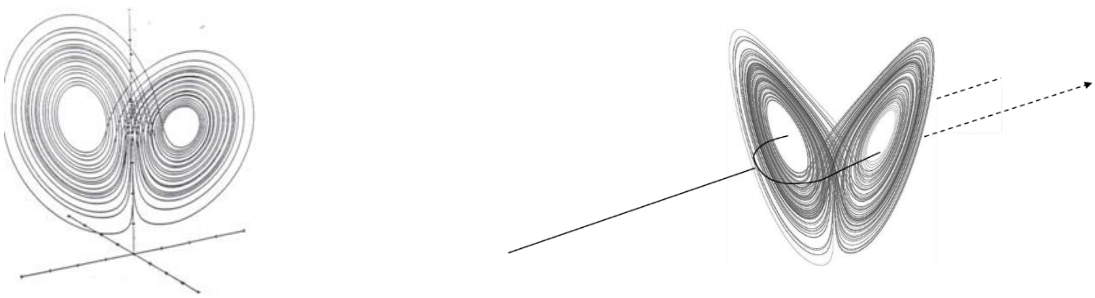
A. **B.** **C.**

Figure 5: Framed by transformative space, coevolutionary processes result in non-linear dynamic systems (A.) in its elementary setting, and at multiple levels of existence, either by (B.) slow transformations in a progressing environment or by (C.) bifurcations and transitions, or a combination of these.

15. What if the unexpected happens?

The Complexity Sciences see a bifurcation as a transition moving towards another level of temporal stability. This transition can involve a coevolutionary process in which structure (object orientation) and function (intersubjective valuing) will fundamentally change, coupled as they are, in conjunction with each other, moving towards an 'undefined becoming' (Figure 2; Boelens & De Roo, 2014; De Roo & Rauws, 2012). As a transformed construct, it will continue to develop further at a new level of existence (Figure 5C).

The evolution of settlements and settling societies, described as 'the archaeology of innovation' of settlements by Van der Leeuw (2009), exhibits various levels of existence. It starts with nomads, who must 'move around' at moments when resource run out. The period of settlement started in response to what nature had to offer, after which there was a period in which settlers gained control over nature and its potential. This was followed by institutional power over organized structures, which emerged from within settlements. This became the basis for revolutions of innovation, among them the industrial revolution, which consequently led to a civil society and a notion of social justice in the late twentieth century. The twentieth century was a time of massive transformation, producing multiple levels of existence in short periods of time. Today, the notion of settlements becoming places where the local and the global meet is definitely gaining attention. Moreover, we can already anticipate likely leaps towards new levels: sensing and aware environments, with cameras and sensors everywhere, and the revolution of the virtual. Some of these steps that transform settlements may be slow (Figure 5B), while others are real revolutions (Figure 5C) and push settlements through rapid transitions. As the spiral ascends, settlements exhibit more complexity and include and transcend the previous ones.



A. **B.**

Figure 6: Singular-hyperbolic attractor (A.) showing the variability of factors of three equations affecting the pathways (B.) open to a chaotic system (weather)

Revolutions are rapid and sudden transformations which are unexpected and involve substantial uncertainty: "key moments of temporal compression" (Jessop, 1997). In the Complexity Sciences, a revolution is best seen as a bifurcation, or the consequence of circumstances disrupting the system's transformative space, with the system pushed off track. In the words of Jessop (1997): "This is pursued from outside entrenched positions, resorts to disrupt established structures of dominance". The system will have encountered a turbulent environment which generated 'strange attractors'. Figure 6 presents such a 'strange attractor', also known as Lorenz's 'Butterfly Effect', which is the result of turbulence affecting the steadily progressing system and the conditions which kept it meandering.

These conditions can best be seen as 'constant' factors in equations that are supposedly linear but suddenly lose their fixed 'status' due to turbulence. Consequently, these factors begin to vary, influencing the pathway of a system in a non-linear manner. Here (Figure 6B), the system is pushed in one of two possible directions – thus, entailing a bifurcation. Viewed together and plotted on three-dimensional axes, these 'contextually affected' factors jointly present the 'strange attractor': it is a new kind of order (Coveny & Highfield, 1995).

Such a bifurcation, with the 'constant' factors shifting value, is part of daily life. Consider a motorway under normal conditions. All cars would drive around 120 km/hour: a constant factor labelled as the 'maximum' speed limit. Say the time it takes for one of the drivers to go from home to work is an half hour. The question would be: How far is the trip to work? This would lead to the following calculation: $y = ax = 120.1/2 = 60$ km, with 'a' being the 'constant' fixed at '120'. However, one day, due to repair work on the motorway, one of the two lanes is blocked, and cars have to reduce their speed substantially. Suddenly the 'constant' factor is no longer constant, with its value going down to 70 km/hour. Obviously, this has real consequences, as it takes much longer to get to work.

What is important here is contextual interference. Due to changes in the context, in this example, the decision to repair parts of the road, the road's function is reduced, the maximum speed limit is no longer a factor that is stable, and the predictability of the arrival time or duration of the trip evaporates. The concept of contextual interference explains changes happening in the context and affecting the system and its trajectory to an unknown degree.

This is precisely what Lorenz discovered with his weather model in 1963, based not on one, but three equations. Fluctuations in the context could mean the end of constant factors and their replacement with variability, uncertainty and non-linearity. This non-linearity in the system's behaviour is the consequence of the system bifurcating. Such bifurcations occurring in traffic and weather systems also appear everywhere within the urban and are therefore relevant to planning.

In chaos theory, a bifurcation is considered as the moment a system encounters an unstable environment liable to cause the system to change course, pushing it in an unknown direction (Ruelle, 1989). The unstable path, the meandering route and the circular trajectory within contingent transformative space, defined by Figures 3 and 4, will evaporate. This also means the end of a period of *slow transformation*. The relative stability of the course towards which the system was initially 'attracted' dissolves or disintegrates in turmoil, with the system entering an environment which permits multiple options for the system to evolve further. It leaves the system no choice but to transform in undefined directions, *adapting* to new environments, while internally going through a process of *self-organization*, in an attempt to ensure the system's chances of survival.

The discoveries of Lorenz and others in relation to the behaviour of 'strange attractors' in unstable environments are liberating in the sense that this represents a realistic alternative to a traditional view of a stable world which finds its optimum when reaching equilibrium (Li and Yorke, 1975; Cilliers, 1998). The discovery of 'strange attractors' and bifurcations reveal a world which evolves non-linearly and unexpectedly due to contextual turbulence. Obviously, our daily environment is far more complex than the single equation expressing the consequences of a roadblock or the three equations with which Lorenz was working to explain air movement due to changes in temperature. It explains, however, the intrinsic mechanisms of sudden change, instability and non-linearity.

Our daily environment is full of unexpected change, non-linear transitions and bifurcations. This daily environment is not easily expressed in mathematical formulas and does not comply with such exactness. Alternative means need to be identified to give expression to the transformations and bifurcations occurring in the daily environment. While mathematically understood, 'strange attractors' do not readily present a clear set of 'conditions' from which we can deduce the system's transformative path towards the future. Instead of a slowly progressing transformative process, the system is confronted with a moment of turbulence that has extreme force, pushing the system off track. At this point, alternatives have to be found to frame the system's behaviour.

16. Pushed off track

The system's adaptive and self-organizing processes have not been completely overlooked or ignored within planning (Allen, 1997; Batty & Longley, 1987; Portugali, 2000). However, these processes have only recently received substantial attention within the planning domain (Boonstra, 2015; Byrne, 2003; De Roo, 2016a; Hartman, 2015; Innes & Booher, 2010; Rauws, 2015; Zhang, 2016). There are two ways to explore this further: one is acknowledging the extreme forces that push the system off track, and the other is to consider the response of the complex adaptive system itself. This requires looking into the system's *adaptive transformative conditions*, which are meant to keep the system together while it rapidly coevolves towards another level of relative stability.

Before going into these adaptive transformative conditions, attention will be paid to the extreme forces pushing the system to bifurcate. These extreme forces are such that they disrupt the system's balanced set of complementary contingent conditions, which had been introduced at an earlier stage. At the moment of bifurcation, the circumstances are far from subtle. The interdependent relationship between system and environment is pushed aside by unilateral dominance of the environment, which suddenly *constrains* the system's present trajectory, while *enabling* the system to perform in a completely different way (Figure 6). What this does to the system will be discussed in depth further below, but in essence its structure and function keep on coevolving however in unknown directions, seeking new and mutually dependent relationships with its turbulent contextual environment, with the structure being reshaped and its connected functions obtaining new meanings.

Constraining events can be seen as a push factor for the system shifting track. Enabling events are to be seen as a pull factor, allowing the system to not only shift but to progress in any direction. Figure 7 presents concrete trajectories with bifurcations which relate to the presence of enabling and constraining events.

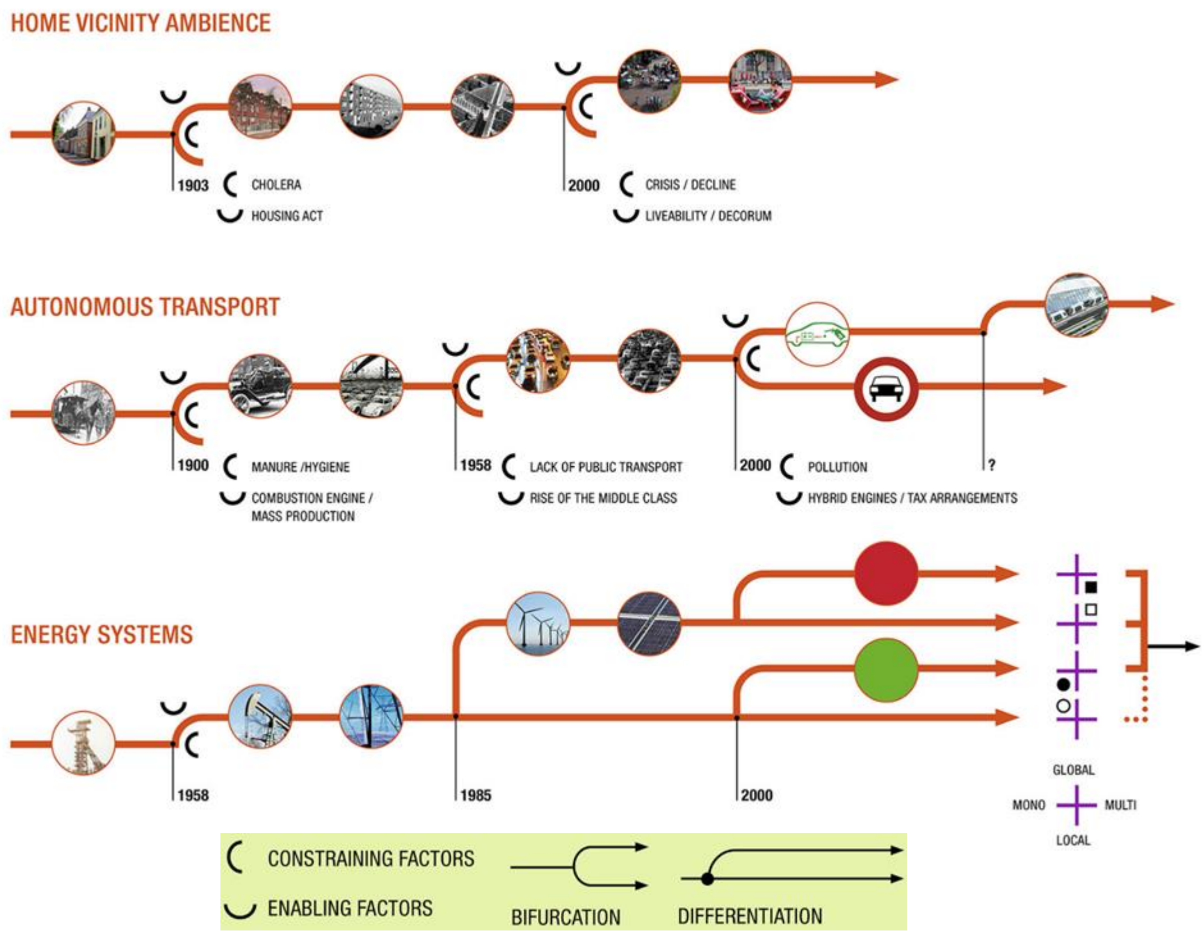


Figure 7: Trajectories encountering moments of instability as a consequence of enabling and constraining events, resulting in bifurcations and differentiations (De Roo, 2014: 211)

The first example in Figure 7 presents residential area development, here termed 'home vicinity ambience'. In the distant past, there were few regulations supporting liveable housing environments. At the turn of the nineteenth century, cities were greatly constrained by disease. Highly contagious cholera led various European countries to introduce legislation intended to prevent such diseases from spreading (Wagenaar, 2011). This marked the beginning of serious spatial planning (De Klerk et al., 2012). Consequently, housing programmes were established. Cholera can be regarded as the constraining factor. And the new legislation proved to be an enabling factor for new and highly planned developments. This legislation supported much more than a healthy environment. While the planning regime remained in place, various developments occurred throughout the twentieth century which affected ‘home vicinity ambience’ and the liveability of a neighbourhood.

Another fundamental change emerged with regard to home vicinity ambience, around the turn of the twenty-first century. This started relatively slowly, for example, in the Netherlands, authorities and housing corporations were no longer able to ‘control’ or guarantee environmental quality, and residents were invited to take responsibility (Tonkens, 2014). The 2008 financial, housing and mortgage crises only made this desire to share responsibility more prominent. These crises can be viewed as a constraint. Enabling factors can also be observed, with various residents collectively taking the initiative to explore, maintain and develop public space near their homes (Warren, 2009): A rise in urban food farming, collective gardening and other initiatives.

Another example (Figure 7) starts with horse-drawn carriages, which were a common mode of transport at the turn of the nineteenth century. Horse manure (constraining factor), however, began to contribute substantially to cities becoming smelly and unhealthy places (Wagenaar, 2011). The combustion engine (enabling factor) allowed the horse to be replaced with an alternative mode of transport without the negative side effects of the horse. It was the beginning of the rise of the car within the urban environment.

In the 1960s, the rise of a car-driven society resulted in multiple car ownership in each family. Thanks to a rapidly emerging middle class the mass production of cars exploded. In particular, the lack of public transport in the US (strategically bought out in the run-up to the Second World War by various car companies with the intention of allowing the railroads to go bust: Kunstler, 1993) supported this process. The car was ubiquitous and people wanted to be able to go everywhere using their cars.

Even before the turn of the century, various strategies were being proposed and implemented to constrain the omnipresence of the car and restrain the use of cars, in particular in city centres and residential areas (Newman and Kenworthy, 1999). The car had become a destructive force in urban life, with traffic jams, noise pollution, smog and a lack of recreational space (constraining factors). Hybrid and electric cars (enabling factors) are a response to some of these nuisances. Cars will probably soon be able to drive autonomously, with the car interacting with the environment to keep itself on course and making use of sensors connected to the internet. No doubt this will again result in a bifurcation and a fundamental change in our understanding of road transport.

The third example (Figure 7) concerns the transformation of the energy system, an example used before. Rather than going into the transformations in detail – they more or less speak for themselves – what is more relevant here is the kind of transformation which can be observed. The transformation of the energy system includes various junctions at which structural differentiations from the main electricity system occurred, resulting in trajectories which evolved in parallel to the main energy system (Van Kann, 2015); for example, the development of local smart grids, which are essentially designed to fine-tune the generic electricity network to local conditions and create a tailor-made structure. While smart grids take the local conditions of the consumer into account, wind turbines and solar cells are local units of electricity production, making the best use of local conditions. Again, this is a structural innovation, while functionally there is not much change to be seen.

Nevertheless, there has been a functional change, in that wind turbines and solar cells change the source of energy from fossil fuels to renewables. Therefore, this change has a substantial impact on society's efforts to become sustainable. Its symbolic value cannot be underestimated. Under the 'renewables' label, wind turbines and solar cells open an entirely new field of energy production, including heat grids, cold-heat storage, thermal heat, biogas, biomass, osmosis energy plants and tidal energy (De Boer & Zuidema, 2015). All these activities can be grouped together into what we could call 'integrated energy landscapes' (Noorman & De Roo, 2011). While the various steps described here concern structural differentiations resulting in parallel trajectories which lead to integrated energy landscapes, various functionalities – the 'prosumer' replacing producer and consumer (Steg et al, 2015), increasing local responsibility, the desire to become autarchic, alternative financing arrangements, the rise of local energy entrepreneurs and so on – have also changed. Consequently, the energy system has experienced a transformation through which structure and function have been fundamentally altered, while the traditional system partially remains in place.

What these examples show is that a turbulent environment generates constraining and enabling conditions to which the system responds, resulting in a coevolutionary process affecting the system's structure and function, which evolve in directions unknown. This brings us to the final and third step in our reasoning about non-linearity. After addressing slow transformative change and the relevance of the system's contingent conditions, as well as bifurcations pushing the system off track, we now come to the complex adaptive system's capacity to coevolve throughout the process of transition (Cilliers, 1998; Geels, 2013; Miller and Page, 2007; Rotmans et al.,2012). This process of a coevolutionary transition needs further exploration.

17. The complex adaptive system and its adaptive conditions

Some characterizations of complex adaptive systems have already been discussed. We have seen that they are both robust and flexible, enabling them to survive as systems while adapting to a changing environment. In a period of slow transformation, the system's robust layer is dominant. Bifurcating and in a process of transition, the system's dynamic layer will increasingly take over. Both the structure and function of a system are likely to coevolve in an unknown direction through a process of transformative transition, which is the system's adaptive strategy. In these dynamic times, a contingent relationship based on knowable conditions is replaced by the system's adaptive conditions. These *adaptive transformative conditions* have the characteristic of a balanced relationship while going through unknown processes of self-organization and adaptation. In retrospect the system going through this process of transition might (and assumingly is likely to) show contingent relationships, however there is not much to say 'a priori' about what these represent. Therefore a more aggregated perspective is what remains. The system 'whose internal features best match the demands of their environments will achieve the best adaptation' (Scott, 1981: 89), with 'the best' to be read as 'balanced'. As the system persists, its structure and function, or its setup and identity might completely and fundamentally alter. The process of development from prehistoric settlements to the urban regions and metropoles of today, and the changing identity that accompanies this is a good example of this process of transformation.

Van der Leeuw (2009) is not alone in considering human settlements to be an example of non-linear development and the behaviour of complex adaptive systems. Various urban planners (Allen, 1997, who worked with Ilya Prigogine; Batty, 2005, 2010; Byrne, 2003; Portugali, 2000, 2009, 2011, 2012, who also works with Hermann Haken; Rauws, 2015;

Verhees, 2013; Winestock, 2010; Zhang et al., 2015) consider cities as complex adaptive systems. These complex adaptive cities have been transformed, from being not much more than nodes on trade routes and river and mountain crossings, into markets, which at some point required protection, leading to defensive walls, and so on, heading towards the industrial revolution with its enabling and constraining conditions, producing the twentieth-century city, which can variously be characterized as booming, functional, congested, communicative or progressive, or as a centre of knowledge and learning, leisure and entertainment. 'Finally', cities have become places where the local and the global meet (Sassen, 1992).

Having arrived at the here and now, how do we view the coming leap towards the future of cities: will they perhaps dissolve, no longer be the place to be for humans the moment the internet takes over most of the connective capacity which make cities relevant? Who knows. However, cities are quite flexible and have gone through various cycles of progressive change, while being simultaneously robust: thus far, few cities have disappeared.

Therefore, transformative space, with contingent conditions and its slow transformative mode, cannot be the only point of reference for understanding the city's transformative capacity. Adaptive and self-organizing behaviour is also relevant, in particular for coping with outside interference affecting the system. Its adaptive response to external circumstances works its way downwards, resulting in self-organizing mechanisms which reshape the system and its subsystems. As the system is in an interdependent relationship with its subsystems, as well as with its contextual environment, this means the adapting system and its subsystems will in turn affect the contextual environment. These self-organization processes have been discussed by various scholars both within and beyond the realm of planning (Bak, 1990; Boonstra, 2015; De Roo, 2016a; Portugali, 2000; Rauws, 2015; Zhang et al., 2015). Here, attention is paid particularly to the conditions which 'condition' the system's transformative behaviour with reference to the interdependency between the internal and external: these will be called *adaptive transformative conditions*.

These adaptive conditions not only allow the system to adapt and self-organize, they also characterize the system and give it identity. Moreover, these adaptive conditions are essential for the system to remain in a healthy state while bifurcating towards a new and relatively stable level of existence. There is a possibility that *these adaptive transformative conditions are not only relevant to a single transformation, but might be expected to remain relevant as the system's structure and function coevolve through various transitions and bifurcations*. This would be a consequence of the internal structure of complex adaptive systems.

This internal structure is considered to consist of two internal layers resonating with each other and to which the adaptive conditions relate: a robust layer and a dynamic layer (Figures 1B, 2B and 8). For a city, this could mean a robust layer representing property rights (Webster & Lai, 2003) and road infrastructure, while a dynamic layer could represent processes of gentrification, powers reaching out to new environments and contexts, such as a central business district, the creative arts, yuppies and – recently – new collectives resulting from the rise of a critical society (De Jong, 2016). Both layers within the complex adaptive system resonate with each other, are interdependent and reflect the system's internal and external negotiations.

This is another balance-seeking process, through which the complex adaptive system can be explained. This process relates to four adaptive conditions which are complementary to and in balance with each other, moving towards a configuration which depends on the turbulence of the environment: the first of the four conditions negotiates between internal robustness and external uniformity, the second between internal robustness and external diversity, the third between internal dynamics and external uniformity, and the fourth between internal dynamics and external diversity (see Figure 8A & B; De Roo, 2015).

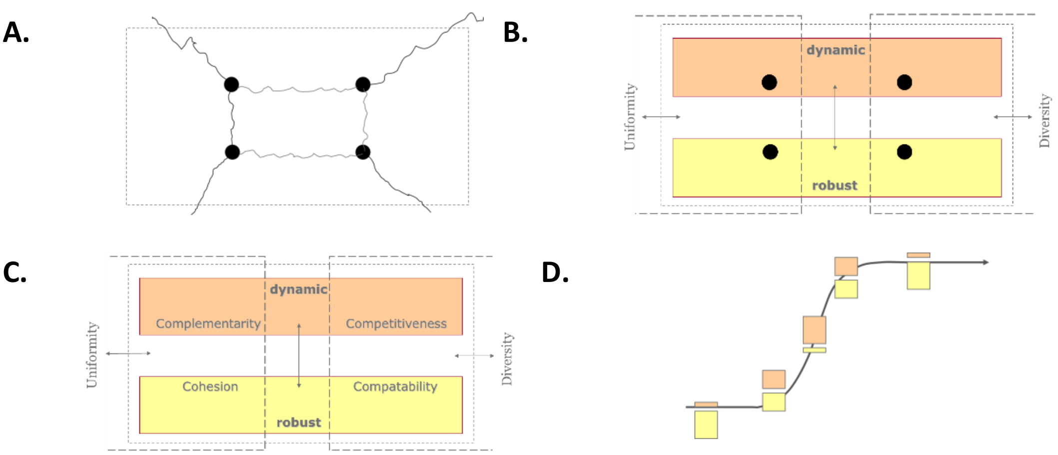


Figure 8: A dynamic systems model: A. four adaptive transformative conditions seeking balance; B. captured by a complex adaptive system – see Figure 1; C. for spatial-economic development; D. undergoing a transition – see Figures 2 and 5 (De Roo, 2012; 2015)

The assumption made about the four adaptive transformative conditions becomes obvious in the model used to address a complex adaptive system going through a process of spatial-economic transition (see Figure 8C). In the case of spatial-economic transition, the complex adaptive system is conditioned by four adaptive conditions: cohesion, compatibility, complementarity and competition. Everyone is well aware of cities and regions *competing* with each other to be the best culturally and industrially, the most connected and so on. Every effort to present a city or region in the strongest possible way is valued by many. Competition represents a dynamic tendency to seek to be distinct, unique and potentially relevant in a diverse world.

However, competition on its own leads to the overlooking of those issues which are not strongly represented, which could easily lead to an imbalance. Therefore, it is crucial for a city or region to also *complement* others (Jessop, 1997). A region, city or neighbourhood with leisure qualities can complement an adjacent region, city or neighbourhood which is strong in industry and services (Hermans & De Roo, 2006). Being complementary, as a condition, means ensuring that all relevant qualities necessary to connect with a turbulent environment are addressed, although perhaps in conjunction with external parties.

While these dynamic interactions with the outside world reveal the capacity of systems to develop new growth paths (Boschma, 2015), these will not be successful if the robust layer of the complex adaptive system is ignored, or worse, if it does not exist. *Cohesion* means a city or region has the right to call itself such because it provides all the essential factors and they function more or less effectively. *Compatibility* demonstrates that these factors are – to some extent – also shockproof. If one factor or function drops out (e.g. a relevant economic activity suddenly disappears), the urban or regional economy is resilient enough to absorb the disruption. In this respect, Boschma and Frenken (2015) referred to 'related diversification', which is supportive of compatibility, claiming that '[r]elated diversification in regions is the rule and unrelated diversification the exception'.

In the case of urban and regional development, a complex adaptive system can be considered balanced if attention is paid to, and a shared investment is made in, competition, complementarity, cohesion and compatibility. For other issues, such as neighbourhood renewal (Nienhuis, 2014), or the rise of the virtual within the urban (De Roo & Yamu, 2017), specific adaptive conditions will have to be formulated to determine whether these systems are healthy, fit and balanced in turbulent times.

Figure 8D depicts how a transition can evolve while bifurcating. From the moment the system is constrained from continuing a steady meandering trajectory, the robust layer will begin to detach from its environment. This also means that the relevance of the contingent transformative conditions that relate to the robust layer will decrease. With this relationship losing touch with its environment, the system is no longer fully or well embedded within its environment. The robust layer remains relevant as that on which the dynamic layer can build; however, this occurs in a process of interaction with the contextual environment and a reaching out to seek new connections with the environment, with the dynamic layer taking the lead.

As early as 1890 (!), Marshall (1961: 271) described this possible substitution of internalities with externalities. Currently, much attention is being paid to 'resilience', often understood as the capacity to absorb impacts from outside while remaining intact. However, the idea of resilience including dynamic processes of transformation, allowing the system to reach a more desirable trajectory, has also arisen (Horlings, 2017). This is captured in the notion of 'evolutionary resilience', which not only includes mechanisms such as sustenance and renewal. Evolutionary resilience relates to the system's capacity to adapt and transform (Franklin, 2017), and to be prepared and persistent (Davoudi et al., 2013: 312). Although framed slightly differently, these capacities resonate with the four conditions considered here to be relevant to a complex adaptive system undergoing a rapid transformation or sudden change.

While going through a rapid transformation, the dynamic layer of the compact adaptive system will become dominant, metaphorically seeking new ground. Informed by its adaptive transformative conditions, the dynamic layer will reach out to the external world, looking for a new and better fit. The moment this fit begins to develop and connections between the system and the external world seemingly start to work again, even beginning to strengthen, the dynamic layer will retreat, allowing the robust layer to take over again. The robust layer will build on newly discovered, fruitful connections with its new environment, seeking a new balance, assuming these connections will be sustained for some time.

If this works out well, the system will have reached the end of the transition. A new and relatively stable trajectory will lie ahead, within which the complex adaptive system will continue to progress. This progression will be less dynamic than during the period in which the system bifurcated and coevolved along an unknown path. Having reached a different level of existence, the system will again connect with a relatively stable transformative environment (Figures 2 & 9), its contingent conditions and their relatively defined terms, which are instrumental to the system's progression. It is assumed that the contingent transformative conditions are the same as before the bifurcation. However, having reached a new level of relative stability, the system's structure and function have fundamentally changed. In this respect, a new system is born, with a different kind of behaviour, which comes with new possibilities.

While transitions produce systems that have fundamentally changed, it is assumed that the adaptive and contingent transformative conditions of these complex adaptive systems are quite persistent, in the sense that they could readily survive several if not all transitions. This has, however, not yet been subject to in-depth research. Therefore, the persistence of these conditions and their 'anchoring' qualities are necessarily an assumption and worth further investigation. It is assumed that the adaptive conditions not only keep the system together, but also allow the system to adapt externally and to self-organize internally. They give the system an identity which is maintained throughout a sequence of transitions.

18. Institutional consequences of non-linearity

This abstract reasoning about contextual and internal change, a world in a state of becoming and the manifestations of slowly meandering and dynamic, bifurcating transformations shows how autonomous and discontinuous change may be a relevant factor in understanding the world of which we are a part. While this understanding undermines the quest for certainty and for a predictable world, it provides knowledge about conditions of change.

These conditions allow systems to transform in a coevolutionary way. Systems in a process of transformation generate temporal, dynamic patterns in accordance with the system's transformative conditions, through which the system's structure and function change. *Transformative conditions are simple, relational, connected and contingent attributes or codes, which define a system's transformative space and its capacity to remain balanced while it is transforming, in terms of situatedness (object orientation) and discourse (intersubjectivity).* Balance concerns the system's response to the transformative conditions, through which the system remains fit internally (self-organizing) and externally (adaptive), while being in flow, out of equilibrium and in an interdependent relationship with its environment. In other words, change is not random, *change is conditioned*.

The fact that the world is in flow, with change all around and unavoidable, is therefore not necessarily problematic. Central to the argument put forward here is the understanding of transformative change as contributing to development and change as a consequence of transformative conditions, transformative space, coevolving transitions and adaptive system behaviour. This understanding is not part of the traditional vocabulary of planning theory and practice, despite the world and our daily environment being full of such changes, developments and transformations. Here, transformative conditions, coevolving transitions and adaptive system behaviour are introduced as drivers of spatial change and as therefore relevant to spatial planning.

Cities do not simply appear from nowhere, emerge out of bricks and concrete, grow linearly or result from a planner's 'command-and-control'. Cities coevolve, with the various structures and functions of cities transforming in a non-linear manner, through which cities fundamentally and discontinuously change, physically and socially (Shane, 2005; Weinstock, 2010). This is a path of discontinuous adjustment moving towards an appreciated fit (whatever that is) between what is valued by communities and the changes which have emerged within the physical and social environment. Such a transformative path will not only change the city but obviously also transform its communities. Along this coevolutionary path, the institutional reality of cities will also be repeatedly redesigned.

Traditionally, the institutional focus has been on conventions which relate to a factual reality and a technical rationality; for example, dikes are meant to keep the water out, bridges are meant to cross streams preventing people from getting wet, roads ensure that various spatial functions are connected, and balconies are meant to be secure. This is an institutional focus that is almost entirely *content* based and goal driven.

Contemporary planning is heavily influenced by the communicative turn. This means a shift towards conventions which relate to an agreed reality and a communicative rationality. While a technical rationale assumes certainty, a communicative rationality frames actions in uncertain and multiple connected environments (Figure 1C). For example, to identify the moment that a neighbourhood is in decline and requires renovation, all parties involved have to reach some sort of consensus in support of a collective understanding and collective action. In other words, they have to agree upon a situation to be able to act accordingly, and in an institutional setting which is strongly *process* driven.

Both planning rationales are more or less centred around decisions regarding a world that ‘is’ (Figure 1C: t = 0; Figure 11B). The technical rationale concerns decisions about problems to be tackled by finding a solution that overcomes the problem completely and permanently, preferably representing a desired world. This is known as goal maximization. The communicative rationale concerns decisions about problems that go through a process of interaction, resulting in appreciation by all parties involved. This is known as process optimization.

The world of issues between the technical rationale, factual reality and goal maximization, and the communicative rationale, agreed realities and process optimization (Figures 1C, 4, 10 & 11) has never been completely without autonomous, spontaneous change. This change, however, was usually seen as an anomaly; as an inconvenient development or a consequence of humans being limited, and therefore something to be overcome. Due to these ‘anomalies’, plans and their results needed evaluation and correction, which is what planners continued to do during the twentieth century. In the 1960s, scenarios of possible realities became a popular, alternative approach to coping with uncertainty and change. Scenarios can be quite supportive of adjusting actions in processes of planning and purposeful interventions. This was followed by the communicative turn in the 1990s, and its shift of focus to an agreed reality. Only recently have some planning policies incorporated notions of non-linear transformation. The policy of ‘energy transition’, for example, is an intentional intervention based on an anticipated transition away from fossil-fuel based energy towards more sustainable energy sources (Rotmans, Loorbach & Kemp, 2012). In some countries, adaptive water management is a response to the impossibility of keeping water out under all circumstances (Tempels, 2016). These new kinds of planning policies are promising steps towards incorporating the perspective of discontinuous change.

Putting emphasis on a world of 'becoming' demands another kind of rationality – a non-linear kind of rationality. This is a rationale that frames discontinuous change, transformative space and adaptive behaviour; a rationale that considers this becoming world first of all, as change that is conditioned; a rationale that generates transformative conditions as anchors to hold on to in a transformative environment; a rationale feeding spatial planning with conditions that are key to purposeful intervention and an institutional design that 'works' in a transformative environment.

This rationale has consequences for institutional behaviour, its design and its response to change. In addition to a focus on content and process, the constructed, agreed, induced and regulating conventions, and the intended actions and purposeful interventions which these generate, institutional design should also pay attention to transformative conditions which are part of and have an effect in a world in flow. These are contingent and adaptive conditions through which a reality, a situation and a system can be understood, while performing in a discontinuous state of autonomous and spontaneous change.

Energy transition and adaptive water management have been mentioned as policies which relate to non-linearity and a world in flow. Energy transition is about policy anticipating an assumed transition to come. Adaptive water management is about practices which are meant to bend in accordance with developments which might fluctuate over time. However, that is not all. Policies with an eye on non-linearity and a world in flow might be keen to enhance the possible positive effects while minimizing the possible negative effects. An increase in cyclists, for example, may be one positive effect of a policy of traffic restrictions for cars. Accommodating this increase in bicycle use could support further growth in the number of cyclists. Gentrification, in contrast, might be seen as a negative effect of autonomous change in the urban population. The negative effects of gentrification can culminate in unpleasant disturbances among groups of citizens, or lead to neighbourhoods declining, which might demand policy interventions through which the negative effects can be reduced to an 'acceptable' level.

A more neutral approach, but nevertheless helpful in adapting to a non-linear and spontaneously transforming reality, is to see how such a transforming reality generates or adds to patterns which might be considered to be the most appreciated outcome. In the words of Jessop (1997): "Through self-reflexive calculation and concern about how a system's own operations will ultimately react back on its own future development through their mediated impact on other systems". For example, 'elephant paths' on grassed areas reveal people's favourable routes. It would be unwise to ignore these patterns. No doubt, this is easier said than done. In most, if not all, cases, an intervention or a policy response – even if it bends in accordance with or enforces a controlled and predefined outcome – triggers additional developments and additional patterns. People will relate to spontaneous and purposefully produced developments and patterns, which also have an effect on the development of space and place. This is perhaps the first and most relevant step to be taken by institutions and policymakers who are attempting to incorporate a non-linear point of view and adopt the notion of a world in flow.

One can only conclude that, like any reality, institutional reality is also open to change. Consequently, this institutional reality will also reveal transformative, coevolutionary patterns through time. The question is how this institutional reality incorporates transformative conditions. Understanding these conditions, brings to the fore a different kind of knowledge about reality (Duit & Galaz, 2008): not factual knowledge or knowing what is agreed upon, but *informed knowledge about the possibilities of transformative space, about the adaptive and self-organizing capacities of systems and their contingent and adaptive trajectories, and therefore about the conditions of non-linear, transformative change*.

To summarize what has been proposed thus far: in relatively stable periods, the contingent transformative conditions representing a system's robustness will seek a balance between contingent conditions and, in accordance with the situation at hand, a slowly transforming environment. The adaptive transformative conditions become relevant in times of turbulence, bifurcation and transition. The more turbulent the environment becomes, the more the adaptive conditions representing the system's dynamics will take over and lead the system's transformative process towards a new period of relative stability. This knowledge about and awareness of the conditions under which a system transforms can inform the planner, decision-maker, politician and the public when considering the impact and direction of a trajectory of spatial and societal development.

With this insight into the system's transformative behaviour, an institutional design can be chosen to support reasoned intervention in, and resonating smartly with, situations that are open to change. This intervention could be considered desirable for various reasons, which have been mentioned above: if transformative behaviour comes with unwanted, negative effects this might lead to interventions to minimize these effects. Another reason could be the desire to benefit fully from the positive outcomes of a transformative process. Spontaneous change can also be created as a consequence of purposeful policymaking. Obviously, attention might be directed to the system itself, allowing it to remain 'healthy' throughout process of transformation; or policy might ensure the system is ready for change, to make the best of its adaptive and self-organizing capacities, and be able to seek a good fit internally and with its environment.

Two interrelated models proposed here (Figures 4 & 8) may contribute to an institutional response and a planning approach which could incorporate and work under transformative conditions of non-linear and autonomous change. The first is the model representing slow transformations, transformative space and its contingent conditions, relevant during relatively stable periods (Figure 4). The second model frames more dynamic and turbulent times and proposes adaptive conditions, to which the system responds in relation to its dynamic environment (Figure 8). Figure 9 visualizes the interrelatedness of the models. This interrelatedness means Model 1 produces the transformative space, to which the robust layer of Model 2 responds in relatively stable times. In such times, the dynamic layer of Model 2 is not much present or relevant and the adaptive transformative conditions do not have much impact on the system, if any. Above all, the contingent transformative conditions are guiding principles to which the system relates while progressing in relatively stable times. The contingent conditions keep the system 'on track' as it follows its meandering path. The moment the system is pushed into a bifurcation, the contingent conditions will lose their potential and the system will undergo a transition. Here, the adaptive conditions take over and ensure the system is involved in a continuous process of negotiation as a balanced whole, while following a trajectory of coevolving change towards the unknown.

In addition to traditional and contemporary planning strategies (Allmendinger, 2009; De Roo, 2003) and their focus on content and process, which work well under the assumption of a world that 'is', it is proposed that two types of situations be added to the realm of planning. These are situations undergoing slow transformation and situations which are confronted with sudden, rapid and dynamic transformation. A situation of slow transformation relates to and is informed by contingent transformative conditions, while situations that are in a state of turbulence while undergoing a transition with an unknown outcome, relate to and are informed by adaptive transformative conditions. In other words, planning, which traditionally related to situations that are fixed and frozen in time, can expand its field of vision and its action radius with notions of reality as sometimes slowly transforming and at other times open to sudden change.

Situations of slow and sudden transformative change, explained by the two 'transformative' models, lead to the conclusion that *open systems in environments 'out-of-equilibrium' are by definition transformative and conditioned*. Consequently, environments have an impact on systems, through which these systems coevolve, adapt, self-organize and transform while, at the same time, these systems affect their environment and subsystems.

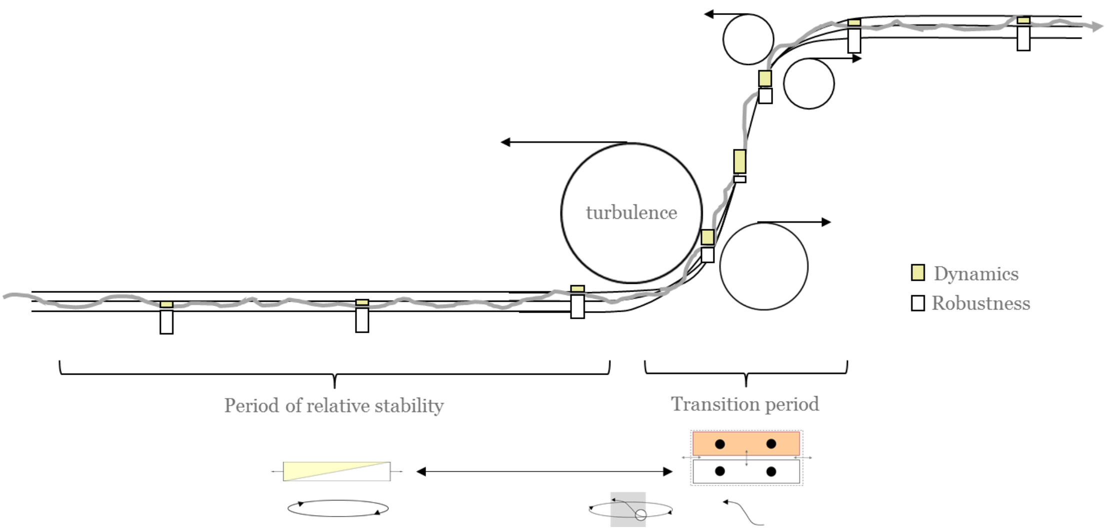


Figure 9: An 'out-of-equilibrium' situation, where the system's meandering trajectory bifurcates enforcing a movement (not necessarily going up) towards a new and healthy fit in a relatively stable environment at another level of development

Consequently, both transformative models can be seen as planning models, and subsequently as models for policy and decision-making. In this contribution, reference has been made to various examples which relate to urban practices to explain both transformative models. The evolution of settlements and settling society has been discussed, along with issues such as housing, water and energy, as well as the turbulence of the 2008 crises that had such an impact on society. There are many more examples. This suggests these models are useful and relevant to decision-making, planning and policy, in the sense that these models inform planners and policymakers about various situations undergoing non-linear, transformative change, and the transformative conditions under which such change takes place.

With reference to both models, planners and policymakers could consider taking the following steps:

A. Identifying the social, spatial or socio-spatial system (and situations, events and planning issues) and its path dependency (historical route) relevant in relation to a particular environment and the process of transformation this interdependence generates.
B. Mapping the system’s contingent and adaptive transformative conditions and their potential for change.
C. Tracking the system’s trajectory within conditioned, transformative space.
D. Understanding this trajectory in terms of situatedness (object orientation) and discourse (intersubjectivity).
E. Weighing the system’s preferential positions internally and externally in terms of its contingent and adaptive transformative conditions.
F. Proposing policy to enhance the positive effects triggered by the system’s transformation, while minimizing the negative ones.
G. Preparing for perturbations that enforce bifurcations and the system going through a period of transition: its adaptive and self-organizing capacity (for a Deleuzian perspective: Hillier, 2011).

In addition to the idea of aiming for a predefined future or ensuring consensus among parties, planners must *be aware of a transformative reality* and *be prepared for change* to allow the system to adapt in the best possible way, profiting from macro-changes, contextual interventions and trends, and self-organizing internally, with the system thus responding to its changing environment. Institutionally, this means considering the possibility of enhancing or reducing the system's capacity to transform. This also means a changing environment can and often should be seen as an opportunity to adjust the system's performance interdependently with its environment. In the Complexity Sciences, this is referred to as the 'window of opportunity' (Kingdon, 1995) and 'possibility space'.

19. Complexity and the planning debate

To fully appreciate the excitement induced by the possibilities a non-linear world might 'deliver' and to open the planning debate to a form of reasoning which comes with complexity, transformative change and non-linearity, one has to be prepared to adjust one's thinking to a rather different mind-set, and be willing to embrace new and alternative understandings. This includes investing in an alternative kind of language which embraces notions such as discontinuous change, transformation, adaptivity, self-organization, emergence, transition, coevolution and transformative conditions (see De Roo & Da Silva, 2010; De Roo, Hiller & Van Wezemael, 2012). This stands in great contrast with the traditional and contemporary planning perspectives.

Rather unique in this respect, however, is 'wickedness'. In 1969, Horst Rittel, a planning scholar working in Stuttgart and Berkeley, made a challenging contribution to the planning debate by introducing 'wicked' problems (Rittel, 1972; with Webber in Rittel and Webber, 1973; and with West Churchman in 1967; and in different terms, see Ackoff, 1974; and Lindblom, 1959). 'Wicked' problems differ from 'tame' problems, which are clearly defined, have clear beginnings and result in – if dealt with properly – clear ends, after which they are 'solved'. 'Wicked' problems have no clear beginning and no clear end, they are hard to define precisely and indisputably, and they cannot be resolved using a technical rationale, at least not completely. To some extent, solutions cannot be found because of the multiple interpretations of what the problem is or might be and what the solution could be.

However, above all, solutions are difficult to find because ‘wicked’ problems are intrinsically and fundamentally uncertain.

Uncertainty can be countered to some extent by fact-finding, complemented by the construction of an agreed reality based on a communicative rationale. This route, however, will definitely not resolve all uncertainties. Some uncertainty will remain, becoming irreducible at some point (Gilboa, 2009). Consider, for example, the uncertainty that might emerge from an agreed reality. Such a reality strongly relates to the moment agreement is reached. What happens if the conditions governing that moment evaporate because the contextual environment continues to transform? What has been agreed upon will no longer be valid. When is the right moment to agree that a neighbourhood is in decline? While a consensus can be reached, it will be difficult to see this consensus as not being subject to the economic environment of a city. What happens to the consensus the moment these economic conditions change and a financial crisis emerges? Such a change will place both the quality of the neighbourhood and the agreements made in a new perspective, with uncertainty everywhere.

There are plenty of other interrelated questions: When will the effect of hypermarkets and factory outlet centres on inner-city development be seen as destructive? And at what point will it be concluded that a city centre has enough car traffic? There are no answers to both questions, at least not exactly and with certainty. Of course, we can take a normative stand, make an educated guess, or throw in some statistics. Models and comparative research can help to some extent to construct an answer which is reasonably convincing. However, the answers to these wicked problems come with many assumptions, due to various unknown factors which could be of influence, although it is unclear which, if any, have an impact, and how much, if at all.

Rittel’s wicked problems did not make it into the mainstream planning debate. The debate at that time was very much focused on bounded rationality, and likely Rittel’s suggestion was not seen as the right answer (Simon, 1960). The leading idea at that time was that humans had their limitations, and these constrained their movement along the route towards the ideal and the possible. Wicked problems did not point to the limitations of human beings but to problems being fundamentally uncertain. Therefore, Rittel’s wicked problems did not offer an answer to the problem of boundedness; on the contrary, the idea of wickedness only added to this sense of constraint and human boundedness. The planning debate eventually took a 'communicative turn' (Fischer & Forester, 1993), ignoring Rittel's message.

Surprising enough, wickedness represented rather well the fundamental uncertainties in the real world observed by the Complexity Sciences. The Complexity Sciences, therefore, rediscovered Rittel and embraced his wicked problems with much appreciation (Conklin, 2005). Wicked problems were thus seen to be a consequence of non-linear behaviour.

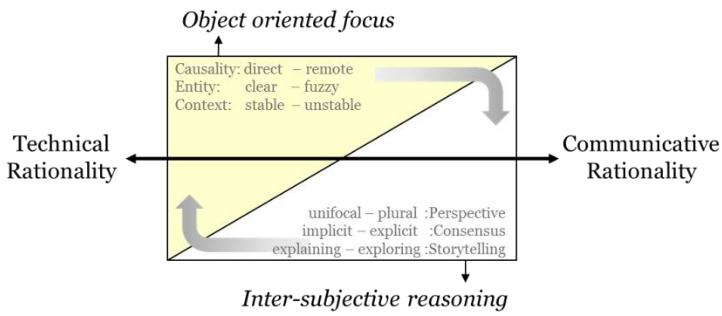


Figure 10: Contemporary planning theory captured in a transformative model of rationalities (De Roo, 2015 & 2016b)

Although it was not wickedness shocking the planning debate to enforce a bifurcation and to push the debate in a particular direction, the planning debate followed a transformative trajectory (De Roo, 2003, 2010, 2012, 2016a), thus also exhibiting transformative behaviour. This debate has been evolving and progressing since the 1950s, which built on the assumption of certainty being within reach and being understandable through facts which are available to us – a technical rationale and a factual reality (Figure 11A).

This assumption of certainty is acknowledged in the left side of Figure 10: there are direct causal relationships, clear and well-defined entities viewed in isolation, and no contextual interference. With certainty within reach, a single true world would seem to unfold. However, this is an ideal which would only work in theory and, in practice, under extreme circumstances. A technical rationale, as the only frame of reference, proved to be an illusion (Figure 11A). Consequently, this perspective came under severe pressure in the 1960s, with various notions, methods and arguments being proposed about constructing a variety of alternatives. The ideal of a single true and certain world was replaced by a notion of various possible worlds: scenario planning. These constructed scenarios were basically linear extrapolations of developments in the past. The alternatives under consideration at that time were all still very much object oriented, and assumed that certainty was still somewhere to be found. Certainty was understood to only be constrained by the boundedness of human beings (Simon, 1960), so they had to muddle through, behave incrementally (Lindblom, 1959) and should best follow a mix-scan approach (Etzioni, 1967). This reasoning led the debate to shift slowly but steadily to the right side of the 'object oriented' triangle of Figure 10: the object oriented perspective transformed into remote causal relationships, fuzzy entities and an interfering context. In the 1980s and 1990s, planning practice developed several integrated approaches that could deal with these conditions.

However, the debate in planning theory continued to the point that the idea of certainty was put aside all together. In its place, a paradigmatic 'communicative turn' (Fischer & Forester, 1993; Forester, 1993) was pursued. This is apparent on the right side of Figure 10, which entails a leap into the realm of intersubjective interaction. With a plurality of perspectives, the desire and the need for an explicit consensus increased, which brought into view the notion of an agreed upon narrative about how to collectively consider the issue at stake. Although the relevance of society's involvement in processes of planning had already been addressed for some decades by progressive scholars, in the 1990s, the planning community as a whole was finally ready to become participative (Innes, 1995), interactive and collaborative (Healey, 2003). In the words of the German critical philosopher Habermas, 'far from giving up on reason as an informing principle for contemporary societies, we should shift perspective from an individualized, subject-object conception of reason to reasoning formed within intersubjective communication' (in Healey, 1993: 237). This entailed a major leap within planning; a true paradigm shift. It introduced the other extreme to planning theory – the communicative rationale (Figure 11A; Healey, 1997; Sager, 1994).

Coincidentally, or not, this paradigmatic turn took place at the moment the Iron Curtain fell, perhaps making neo-Marxist and critical thinkers such as Habermas, Foucault, Derrida and Deleuze acceptable to the mainstream debate. These 'critical thinkers' represent a philosophy which emphasizes the relevance of intersubjectivity, and the world of valuing, opinions, meanings, power and discourse. More importantly, the communicative rationale meant an approach which would bring about an agreed reality, and an alternative kind of certainty for those situations which were fuzzy, fluid and vague. Obviously, this is a different kind of certainty than the one promised by a technical rationale; however, it was something to hold on to once again. An agreed reality is the consequence of the desire to reach consensus in a participatory planning process. In addition to the planner's role as an expert, the planner also had to act as a mediator.

At the same time, in practice, a rise in interest in communicative processes could be observed, although technical approaches remained popular and necessary. Of note here is that the technical rationale and the desire to maintain a command-and-control attitude are neither dated nor outdated, but have become situational or issue specific. The same is true for the communicative rationale and the desire to take a shared governance approach. The communicative rationale also proved to be idealistic in its approach to the world, and extreme as well in relation to most everyday difficulties. In abstraction there is something quite relevant to say about the difference between the two: A technical rationale is quite valid in situations which are clear, certain and straightforward, while the communicative rationale works in fuzzy, diverse and pluralistic situations with multiple actors who have different interests. In such cases, the integration of policies, approaches, responsibilities and action is recommended. What effectively occurs in these situations is a process of communication between stakeholders. In other words, integration – seemingly object oriented – will not work as a strategy without accepting a communicative rationale. Consequently the responsibility for such situations is often decentralized to a level where these situations first become manifest.

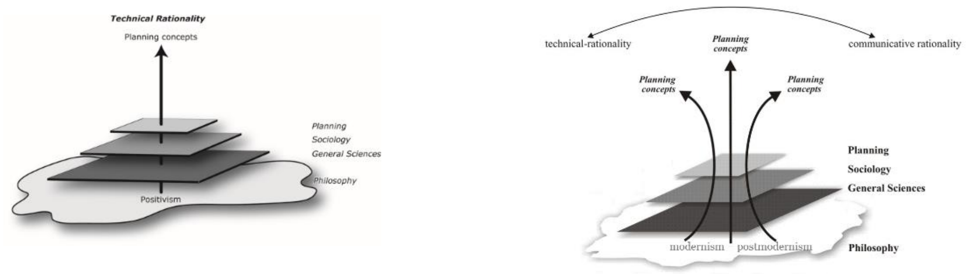
Communication strategies are meant to reach consensus about the issues at stake, the parties involved, their shared responsibilities, their actions and so on. It is not difficult to imagine that the moment such strategies are internalized and resonate well with actions in the empirical world, the situation becomes such that clarity, straightforwardness and factual certainties begin to reappear. The various agreements that had been made explicitly then become implicitly accepted as the truth, and a situation in which the debate is self-explanatory arises again. At this point, a technical rationale might again be within reach and the process comes full circle (see Figures 4 & 10). However, it has been argued that this circular trajectory is only to be expected if the contextual environment remains untouched. In this respect, while the contextual environment within which the planning debate takes place is perhaps not turbulent, it is also not static. However, the alternative, the notion of the debate encountering moments of turbulence which could force the planning debate to bifurcate, has not yet occurred.

Nevertheless, recognizing that a system, situation or debate is slowly transforming, may generate additional knowledge to complement the more commonly understood content and process. In other words, understanding the planning debate itself as in a process of slow transformation may become an asset from which more knowledge can be deduced. This knowledge could further lead to a modelling of the transformation, which would again shed light on what is happening: transformative space and its transformative conditions.

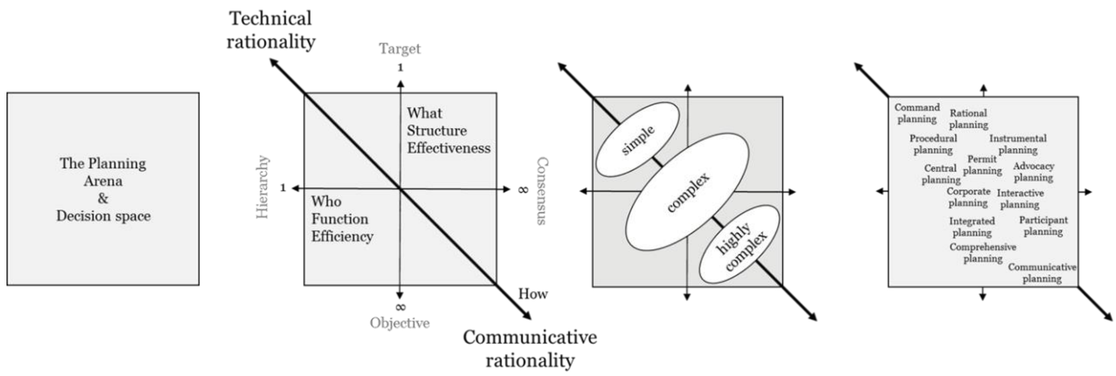
In a situation of relative stability, a reality will unfold which is in line with the contingent conditions that arise and are relevant to transformative space between two extremes (Figure 3, 4 & 10). A contingent relationship becomes visible, as we have seen in Figure 3: a relationship within which behaviour changes from generic to specific approaches, and from procedural to tailor-made activities. To be more precise, it is a post-contingent relationship (Zuidema, 2014): an object oriented perspective which strongly relates to a technical rationale will weaken in favour of intersubjective interaction and a communicative rationale, while shifting along a spectrum (see Figures 10 and 11), with planning issues becoming more fuzzy, fluid and vague. This post-contingent spectrum between the extremes of technical and communicative rationality is what we might refer to as the '*Holy Spectrum of Planning*' (Figure 11; De Roo, 2012, 2013, 2016a).

It is along this spectrum, between these two extremes, that the contemporary debate in planning is evolving. The spectrum more or less positions the development, progression and transformation of the planning debate through time. This debate has been highly inspiring and has continued to progress for more than 50 years, and is still very much alive today (Allmendinger, 2009). While the frontline of the debate is progressing further, the traditional and contemporary debate has not become obsolete or evaporated. All forms of the debate have produced results of value. In particular, it has made clear under which conditions specific realities can be dealt with. Moreover, these realities can be located at various positions along the *Holy Spectrum of Planning*, ranging from simple and straightforward to highly complex, fuzzy and fluid issues or situations (Figure 11B). Each of these realities lying between the technical and the communicative rationales come with a specific perspective. The approaches, actions and interventions will also be specific to the circumstances that relate to the point on the spectrum that is being addressed.

A.



B.



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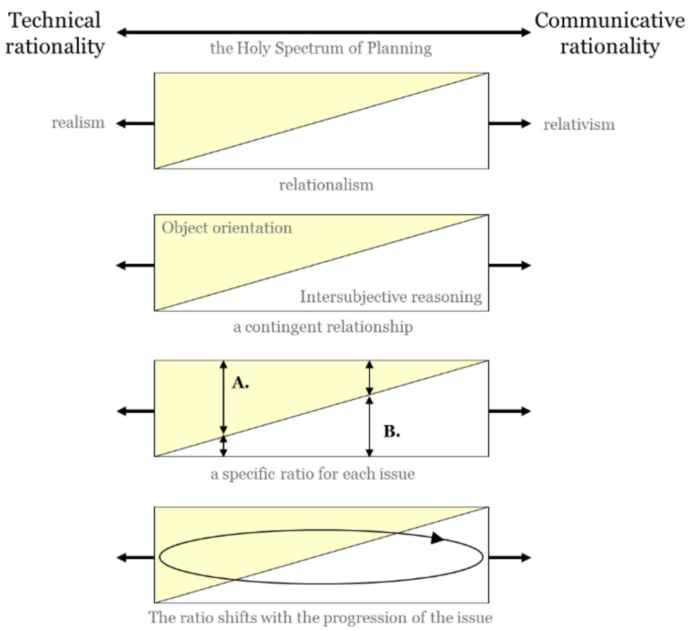

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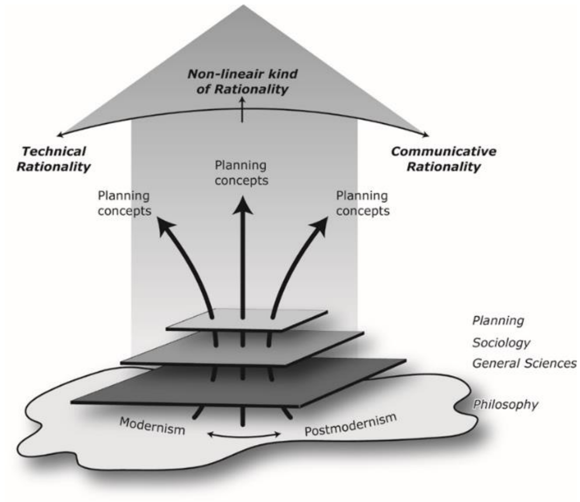

Figure 11: The evolution of *The Holy Spectrum of Planning*: **A.** Traditional ('50) and contemporary planning rationales (De Roo, 2013: 53); **B.** Modelling planning & decision-making by differentiating issues in terms of 'degrees of complexity' (static complexity) (De Roo, 2000; 2003); **C.** The transformative model's contingent behaviour; its proportional structure and transformative character; **D.** The positioning of a non-linear rationale for planning (dynamic complexity) (De Roo, 2010b: 35)

As a means to frame the progression of a situation, issue or system along a circular trajectory, the transformative model (Figures 3, 4, 10 & 11) not only works for emerging settlements and settling societies, but also in relation to the theoretical debate in planning (Figures 10 & 11). The model points out how this *(post-)contingent relationship generates proportional clarity at various positions along the spectrum: a 'given' ratio between object orientation and intersubjective interaction*. In other words, the model presents a synthesis of the technical and the communicative rationales.

The model also provides a *reason to distinguish planning issues on the basis of contingent conditions*. Situating a planning issue to the left in the diagram (A. in Figure 11C) indicates a reasonable amount of certainty, although some intersubjective reasoning will still be required. In other words, whatever the situation, even if it is certain and straightforward, minimal communication remains a necessity. If the situation is considered relatively uncertain (B. in Figure 11C), the issue will be positioned further to the right. This, however, does not mean that object orientation is of no use and a technical rationale is no longer valid. It will remain valid, but no longer as the leading perspective. This also makes clear that integrated approaches (upper right in Figure 10) have a limited object orientation, as intersubjective reasoning will predominate. A differentiated perspective on planning and on planning issues is one of the major accomplishments of the planning debate.

The next step would then be to consider how the *Holy Spectrum of Planning* relates to complexity thinking (Figures 1C, 10 & 11). If the evolution of the debate in planning is to be seen as a progression within transformative space, the planning debate will maintain a balance as it undergoes a set of transformative conditions while moving ahead. The planning debate has gone through various stages, with each stage an acknowledgment that the world is more uncertain than was initially thought or was hoped for in the previous stage. This went as far as accepting that uncertainties should be dealt with through a consensus-seeking process, in which the parties involved are invited to participate in order to reach an agreement, through which certainty is generated (instead of given). This then becomes a new basis to work from: an agreed reality. Instead of attaining predefined goals, the optimization of the planning process is the focus.

Currently, the planning debate is not producing a clear trajectory towards the future, a route beyond the communicative rationale. Although some believe the communicative paradigm is at its end (Schoenwandt, 2008), there is no clear and undisputable alternative presenting itself as the new paradigm. What can be observed in the contemporary planning debate is an increasing interest in a range of alternative planning approaches (Allmendinger & Tewdwr-Jones, 2002; Rydin, 2013), including those which have an awareness of time, transformative change and non-linearity. With regard to the latter, alternatives are being proposed which relate to a transformative, autonomous, emergent, adaptive and self-organizing reality. In such a reality, planning issues are not viewed as isolated problems to be dealt with permanently, or as difficulties which need to be agreed upon and dealt with on the basis of consensus. Instead, there is an awareness of time, emergence and non-linearity: situations, issues and systems are open to change, follow transformative trajectories and exhibit adaptive behaviour. Perhaps this reasoning marks the beginning of a transition towards a new level of understanding for planners with regard to the daily environment within which they interact and work. All that is required is an additional frame of reference in the planning debate: the introduction of a non-linear, transformative rationale.

20. Synopsis

Planning is a social project, with purposeful interventions meant to add value to a civil society (Sandercock, 1975). Through communication processes, the need for and value of such interventions are considered collectively. Communicative approaches are meant to result in commonly defined and agreed upon understandings of issues which could be dealt with by a participative planning regime. These agreements are particularly relevant in situations which are highly normative, fuzzy and undefined. However, such agreements are not only made to reach an agreed reality and come to terms with each other. They are also often made to keep all parties happy with the intention of keeping them on board, but little assurance they will. In other words, there is plenty of uncertainty to be expected despite the agreements made. Furthermore, in communicative processes, it is quite unlikely that certainty, a collective understanding and the continued appreciation of what is agreed upon will remain unaffected, whatever occurs along the developmental path. Here too, the uncertainties cannot be reduced to zero, and will affect the planning process, pushing it in unexpected directions.

Nevertheless, certainty relates to a planning paradigm which is still highly valued. While it can no longer be the basis of a universal kind of planning, it may still be relevant in a situational sense, where certainty is not only thought of as a given but as an essential condition. However, even here, certainty is not guaranteed. Moreover, in practices which include blueprints, vertical decision-making lines and functionality as the leading principles, it must nonetheless be acknowledged that reality is not always susceptible to certainty and control. The predictability of the future to come and the creation of a world according to plan, all the promises made by scientific approaches which are founded on logical positivism and a belief in true knowledge: It is an illusion.

In addition, there is also the perspective of a world in flow, which feeds dissipative systems, through which these adapt and self-organize more or less continuously. This world in flow is to be understood as transformative, within which irreducible uncertainty is not only a given but also an opportunity. A world in flow, the uncertainty that comes with this and the non-linear development that is produced, reflects a transformative environment within which systems thrive and transform. These systems that are capable of transforming, adapting and self-organizing are 'complex adaptive systems'. Cities and settlements are examples of such systems.

This brings us to the Complexity Sciences. Complexity thinking and spatial planning seem almost antagonistic, entailing a conflict of reasoning. Complexity concerns theories of spontaneous, non-linear and discontinuous change. Spatial planning relates to a science of purposeful interventions. At first glance, there is a dichotomy, if not a paradox. Nevertheless the Complexity Sciences, complex adaptive systems, and their non-linear behaviour, which focus on non-linear change at the edge of order and chaos, are all relevant to the discipline of spatial planning.

For most planners, decision-makers and all those involved in spatial intervention in some manner, reasoning in terms of complexity is not immediately comfortable. Some assume it is about issues being complex and therefore beyond their competences. Some stubbornly translate complexity into 'being complicated' and therefore 'being problematic', which – with a bit of luck, good will and a prayer – can be dealt with in due time. The complexity we are concerned with has nothing to do with these assumptions and beliefs.

Complexity relates above all to a dynamic world full of systems that are connected as well as open to transformative change. These systems bend with and are transformed due to environmental interference. They also generate change from within, which may also result in effects in a wider environment. In such a world, leaps, shocks and surprises are all essential and part of the game, they come and go, succeeded by periods of temporary stability. This is a world in which 'windows of opportunity' and 'possibility space' appear. A non-linear understanding means considering the world as undergoing discontinuous change, and as fundamentally uncertain, and that this often occurs and becomes manifest beyond our control.

Should the traditional understanding of a world that 'is' be replaced by a world of 'becoming'? What if revolution and evolution were manifestations of a more realistic reality, and essential to an understanding of a transformative world which coevolves along the way? Would this be the end of planning purposeful interventions? Would that mean there is nothing left but to go with the tide, surf the waves, take things as they come? The conclusion here is this need not be the case: it is surprising to see how much there is to say about planning and purposeful intervention in a world of non-linear change.

If this contribution makes anything clear, it is the possibility of constructing frames of reference for systems which are open to change, understanding the way they transform and behave non-linearly, as well as how they coevolve while seeking a good (balanced) fit internally and externally. Transformative conditions have been identified which allow systems (planning issues) to be defined on the basis of their transformative capacity, in slow as well as in sudden, spontaneous transformations.

In trajectories of slow transformation, the conditions can be seen as the synergy of a dualistic representation of the system: object orientation and intersubjective interaction merging into one specific frame which works well for any open system that is subject to observation. The conditions mark the system's 'transformative space', in which it develops, without dying from inertia (order) or collapsing into diversity (chaos). This transformative space generates development patterns for the system which could result in a circular trajectory. This trajectory would then be the product of a contingent relationship between the system's transformative conditions. If the system is somehow pushed off track and bifurcates, thereby undergoing a turbulent transition process, another set of transformative conditions will keep the system together, adapting externally while self-organizing internally, all in an unknown direction.

These possibilities mark two kinds of transformation: slow transformations according to a pattern or circle following rules of contingency; and sudden, turbulent and dynamic transformations which push the system towards the unknown until a steady state is reached again. For both types of transformations, a model has been proposed to frame the system's transformative conditions. Both transformations work as long as the system remains healthy within a world in flow, which is a world between order and chaos, uniformity and diversity, inertia and disintegration. As long as the system remains at the edge of order and chaos, and remains susceptible to a world in flow, it is likely to remain fit, while transforming internally and externally. *The transformative conditions to which the system responds are to be seen as the system's ordering principles in a dynamic world of change.*

This reasoning can go further to conclude that each open system, situation, issue and environment is by definition transformative. Each system, situation, issue and environment is by definition conditioned. Contextual environments have an impact on systems, through which these systems coevolve, adapt, self-organize and therefore transform, while coevolving, adapting and self-organizing systems also affect their environment.

Systems are conditioned to change: their transformative conditions shape a reality which can be experienced and perceived, and their contingency can be made explicit (at least to some extend). Transformative conditions are relational, connected and contingent attributes which define a system's transformative space and its capacity to keep the conditions balanced while transforming in terms of situatedness (object orientation) and discourse (intersubjectivity). The attributes of these transformative conditions consist of local or situational implications of physical laws, biological rules or instructions, social conventions and digital algorithms, to which systems and their environment respond. These determine the system's behaviour, in conjunction with the observer's perception. Functioning as ordering principles, the transformative conditions produce conditioned transformative space. Within this transformative space, the system undergoes transformation and progression, while seeking a good (balanced) fit internally and externally, representing a world in a state of becoming. Transformative change is therefore not a free-floating enterprise: transformative change is conditioned change. Knowledge about the conditions of change means knowledge about the rules governing order that are relevant in moments of change. Rules can be played with, which opens the possibility of intervention.

The notion of systems being conditioned for change is not restricted to material systems such as cities and settlements and the societies that live in and around them. Along with the transformation of settlements and settling societies, the institutional environment will also transform, seeking a good fit with its material and immaterial environment. Moreover, even the theoretical debate is subject to processes of non-linear change, with the debate coevolving and rationalities being transformed. In other words, the theoretical debate in planning is also conditioned and therefore open to change.

Material, institutional and theoretical systems have the capacity to transform as long as these systems are open to change. The need for this transformation to take place within an environment found between two extremes is due to *the dualistic nature of a world in flow*. The term 'complexity' encapsulates this dualistic nature, which allows systems to live in a world that is 'out-of-equilibrium' and which generates transformative and non-linear behaviour. This dualistic nature seems almost dialectical. While 'dialectics' is seen in philosophy as the synthesis of a dualistic reasoning, it can be argued that 'complexity' is a synthesis of a dualistic nature, with this dualistic nature driving systems to coevolve at the edge of order and chaos.

This dualistic nature is subject to observations by the empirical sciences. The debate in spatial planning is also dualistic, and in two ways: firstly, there is the *Holy Spectrum of Planning*, with multiple realities between two extreme and ideal worlds. Secondly, a step has been taken within the planning debate to embrace intersubjective reasoning in conjunction with a more traditional object orientation to reality.

This world of planning can be positioned and differentiated in terms of various degrees of complexity situated between the technical and communicative rationales. This relates to a static kind of complexity and the possibility of differentiating reality in terms of 'degrees of …'. This approach to differentiating reality is of great relevance to planning and policymaking in grasping a reality that is diverse and plural.

These assets produced by the planning debate are lacking within the Complexity Sciences. However, the Complexity Sciences have had a strong debate on non-linear development, which includes notions such as emergence, transition, adaptivity, self-organization and coevolution. The Complexity Sciences have also convincingly shown how open systems live, behave and survive in a transformative environment. Moreover, the Complexity Sciences have convincingly shown that a closed environment governed by certainty is nothing but an illusion.

If the assets of the planning debate were be incorporated by the Complexity Sciences, the concept of 'social complexity' might escape the abyss of object orientation. Social complexity could be redefined as a concept that is able to merge its object orientation with the intersubjective side of reality. The modelling of the evolution of settlements and the progression of settling societies presented here shows how such a merger can produce a realistic understanding of social complexity and the transformative capacities of settlements and their societies.

This contribution has argued that neither extreme in the planning debate should be seen in isolation from the other: there is a contingent relationship between the technical and the communicative rationales. We have also elaborated on the idea that the somewhat linear, static and a-temporal world of planning is connected to the non-linear, dynamic and transformative world of the Complexity Sciences. It is up to those within the domain of spatial planning to benefit from and incorporate the non-linear reasoning that drives the Complexity Sciences. Non-linear approaches to planning can be developed in addition to traditional and contemporary approaches. This could contribute to a widening and deepening of a differentiated understanding of planning issues in support of choice and decision-making regarding intentional interventions. The argument that planning will lose its way in a non-linear environment has been proven wrong by pointing to the ordering principles that work in a dynamic world of change.

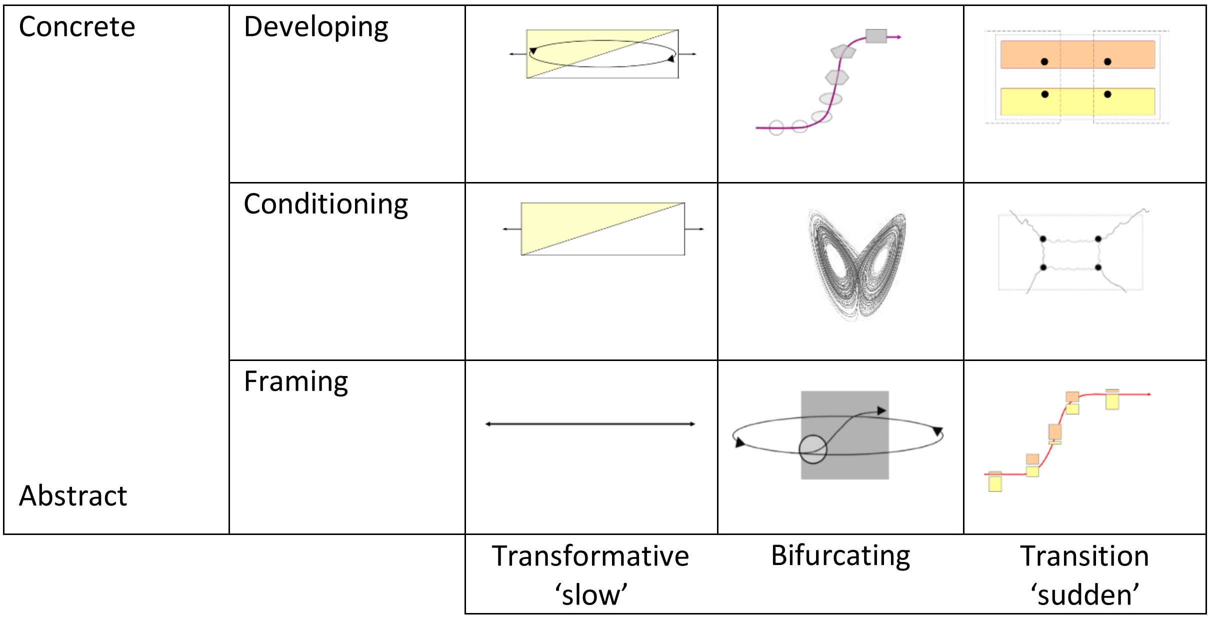

Figure 12: Models and diagrams at various levels of abstraction introduced here to express non-linear development

There are situations in which a non-linear, unstable and uncertain world is more likely than a world which is stable, linear and certain. This does not mean that planners will be outmanoeuvred. On the contrary, this contribution has explored various ways to understand non-linear transformative environments. Figure 12 summarizes the models used in this contribution, and positions them to demonstrate the relationships between them. It is equally important to understand that situations considered as non-linear and complex do not need complex, difficult or impossible approaches. Non-linear situations call for alternative approaches alongside those which relate to factual, possible and agreed realities. There is a world to gain by developing non-linear approaches alongside existing ones. It seems reasonable to suggest that an adaptive form of planning which is sensitive to change would be one of these new approaches. Rather than primarily focusing on content and process, such approaches would focus on the transformative conditions under which reality unfolds and which hold systems together. In non-linear, transformative environments planning becomes conditional. Transformative conditions have been identified as ordering principles which could work well in transformative environments. Transformative conditions can be supportive to planning and its purposeful interventions.

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